SCIENCE, AERONAUTICS AND TECHNOLOGY

FY 2001 ESTIMATES

BUDGET SUMMARY

OFFICE OF SPACE SCIENCE | **SPACE SCIENCE**

SUMMARY OF RESOURCE REQUIREMENTS

	FY 1999 OPLAN 12/23/99	FY 2000 OPLAN REVISED	FY 2001 PRES BUDGET	Page Number
		(Thousands of Dollars)		
* Chandra X-ray Observatory	45,300	4,100	--	SAT 1-6
* Space Infrared Telescope Facility..........	119,700	123,400	117,600	SAT 1-8
* Hubble Space Telescope (Development)	159,600	160,100	168,100	SAT 1-11
* Relativity (GP-B) Mission	61,300	49,900	13,800	SAT 1-14
* Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics..........	53,300	27,500	--	SAT 1-17
* Stratospheric Observatory For Infrared Astronomy	58,200	39,000	33,900	SAT 1-19
Payload and Instrument Development	29,200	13,600	7,100	SAT 1-22
* Explorers..........	205,100	122,300	138,800	SAT 1-27
* Discovery..........	123,900	154,800	196,800	SAT 1-35
* Mars Surveyor..........	227,700	248,400	326,700	SAT 1-40
Mission Operations	117,300	75,400	80,000	SAT 1-44
Supporting Research and Technology	916,100	1,179,285	1,302,800	SAT 1-50
Investments	--	--	13,200	SAT 1-80
Construction of Facilities	2,500	--	--	
Undistributed Reduction	--	-5,000	--	
Total..........	2,119,200	2,192,785	2,398,800	

*Total Cost information is provided in the Special Issues section

SCIENCE, AERONAUTICS AND TECHNOLOGY

FY 2001 ESTIMATES

BUDGET SUMMARY

Distribution of Program Amount by Installation	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Johnson Space Center	19,858	16,466	25,442
Kennedy Space Center	201,321	145,193	185,568
Marshall Space Flight Center	181,230	147,346	126,137
Ames Research Center	105,343	103,556	117,619
Langley Research Center	19,935	12,118	18,524
Glenn Research Center	27,379	24,323	22,504
Goddard Space Flight Center	741,721	764,738	870,508
Jet Propulsion Laboratory	708,730	825,000	985,193
Dryden Flight Research Center	30	75	75
Stennis Space Center	0	35	35
Headquarters	113,653	153,935	47,195
Total	2,119,200	2,192,785	2,398,800

PROGRAM GOALS

Humans have a profound and distinguishing imperative to understand our origin, our existence, and our fate. For millennia, we have gazed at the sky, observed the motions of the Sun, Moon, planets, and stars, and wondered about the universe and the way we are connected to it. The Space Science Enterprise serves this human quest for knowledge. As it does so, it seeks to inspire our Nation and the world, to open young minds to broader perspectives on the future, and to bring home to every person on Earth the experience of exploring space.

The mission of the Space Science Enterprise is to solve mysteries of the universe, explore the solar system, discover planets around other stars, and search for life beyond Earth; from origins to destiny, chart the evolution of the universe and understand its galaxies, stars, planets, and life. In pursuing this mission, we develop, use, and transfer innovative space technologies that provide scientific and other returns to all of NASA's Enterprises, as well as globally competitive economic returns to the Nation. We also use our knowledge and discoveries to enhance science, mathematics, and technology education and the scientific and technological literacy of all Americans.

In accomplishing its mission, the Space Science Enterprise addresses most directly the following NASA fundamental questions:

How did the universe, galaxies, stars, and planets form and evolve? How can our exploration of the universe and our solar system revolutionize our understanding of physics, chemistry, and biology?

Does life in any form, however simple or complex, carbon-based or other, exist elsewhere than on planet Earth? Are there Earth-like planets beyond our solar system?

The four long-term goals of the Space Science Enterprise are:

Establish a virtual presence throughout the solar system, and probe deeper into the mysteries of the universe and life on Earth and beyond—a goal focused on the fundamental science we will pursue;

Pursue space science programs that enable, and are enabled by, future human exploration beyond low-Earth orbit—a goal exploiting the synergy with the human exploration of space;

Develop and utilize revolutionary technologies for missions impossible in prior decades—a goal recognizing the enabling character of technology; and

Contribute measurably to achieving the science, mathematics, and technology education goals of our nation, and share widely the excitement and inspiration of our missions and discoveries—a goal reflecting our commitment to education and public outreach.

STRATEGY FOR ACHIEVING GOALS

Science

The Space Science Enterprise pursues the study of origins, as well as studies of the evolution and destiny of the cosmos, by establishing a continuum of exploration and science. It creates a virtual presence in the solar system, exploring new territories and investigating the solar system in all its complexity. It simultaneously probes the universe to the beginning of time, looking ever deeper with increasingly capable telescopes, scanning the entire electromagnetic spectrum from gamma rays to radio wavelengths. It also sends probes into interstellar space, beginning a virtual presence even beyond the solar system.

The strategy of the Enterprise is to conduct world-class research, to maximize the scientific yield from our current missions, and to develop and deploy new missions within the "faster, better, cheaper" framework of a revolutionized NASA.

A key aspect of our strategic planning is to ensure the Enterprise acquires the advice of the external science community, and in particular the National Academy of Sciences. The Enterprise is also ensuring science community input by utilizing peer review in the Discovery, Explorer and Supporting Research and Technology programs. In addition, there is extensive collaboration with this community, international partners, and other federal agencies, such as the National Science Foundation, Department of Defense, and Department of Energy, in the conduct of our missions, research and technology.

As a visible link to future human exploration beyond Earth orbit, Space Science Enterprise robotic missions help develop the scientific knowledge such ventures will need. In the long term, the Enterprise will benefit from the opportunities human exploration will offer to conduct scientific research that may stretch beyond the capabilities of robotic systems.

Education and public outreach

The traditional role of the Space Science Enterprise in supporting graduate and postgraduate professional education — a central element of meeting our responsibility to help create the scientific workforce of the future — is being expanded to include a special emphasis on pre-college education and on increasing the public's knowledge, understanding, and appreciation of science and technology. The comprehensive approach to education and public outreach developed by the Space Science Enterprise is described in more detail in the October 15, 1996 report "Implementing the Office of Space Science Education/Public Outreach Strategy", available in full on the World Wide Web at http://spacescience.nasa.gov/edu/imp_plan.htm

Our strategy begins with incorporating education and public outreach as an integral component of all of our activities — flight missions and research programs. It focuses on identifying and meeting the needs of educators and on emphasizing the unique contributions the Space Science Enterprise can make to education and to enhancing the public understanding of science and technology. It is directed toward: optimizing the use of limited resources; encouraging a wide variety of education and outreach activities; channeling individual efforts towards high-leverage opportunities; developing high-quality education and outreach activities and materials having local, state, regional, and national impact; and ensuring that the results of our education programs are catalogued, evaluated, archived and widely disseminated. Our strategy supports NASA's overall education program and is aligned with NASA's efforts to ensure that participation in NASA missions and research programs is as broad as possible. It is centered on brokering and facilitating the formation of partnerships between space scientists and a wide range of individuals and institutions across the country engaged in education and in communicating science and technology to the public. It makes contributing to education and outreach the collective responsibility of all levels of management in the Space Science Enterprise and all the participants in the Space Science program.

During FY 2001, we will successfully achieve at least six of the following eight objectives:

(1) Every mission initiated in FY 2001 will have a funded education and outreach program with a comprehensive education and outreach plan prepared by its Preliminary Design Review (PDR).
(2) By the end of FY01, 10 percent of all research grants will have a funded education and outreach program underway.
(3) Enterprise-funded education and outreach activities will be in planning or implementation in at least 34 states.
(4) At least five Enterprise-funded research, mission development or operations, or education projects will be underway in Historically Black Colleges and Universities, Hispanic Serving Institutions and Tribal Colleges, with at least one being underway in an institution of each type.
(5) The Enterprise will provide exhibits, materials, workshops, and personnel at a minimum of five national and three regional education and outreach conferences.
(6) At least five major Enterprise-sponsored exhibits or planetarium shows will be on display or on tour at major science museums or planetariums across the country.
(7) The first comprehensive Space Science Enterprise Education/Outreach Report will be prepared that describes participants, audiences, and products for Enterprise education and outreach programs.
(8) Initial results of a pilot assessment of the Enterprise’s approach to education and outreach will be available for determining whether adjustments in program direction or organization are needed.

Technology development and transfer
A number of enabling technologies have been identified for the Space Science program, and prioritizing them is one of the most important technology planning tasks. These technologies fall into two general categories:

- Technologies that provide fundamental capabilities without which certain objectives cannot be met, or that open completely new mission opportunities. Fundamental enabling capabilities include developments such as high-precision deployable structures that maintain optical paths to within fractions of a wavelength of light. These are required for studying extra-solar planets through optical interferometry, as well as for the next generation of large space telescopes that will see to the edge of the Universe.

- Technologies that reduce cost and/or risk to such a degree that they enable missions that would otherwise be economically unrealistic. Highly capable micro-electronics and micro-spacecraft systems, by virtue of their broad applicability and potential for reducing mission costs and development times, enable missions which would otherwise be prohibitively expensive. The importance of these systems and their commercial potential make them one of our most important technology investment areas.

A well-structured technology portfolio must recognize and balance the importance of both categories. A key aspect of this portfolio is that it utilizes partnerships with industry, other government agencies and universities in the planning, development and implementation of Space Science missions. Many capabilities have been transferred and infused into industry from DoD or NASA core technology support, and the space science research community uses the resulting industrial space infrastructure for mission planning and development. Industry partnerships allow for a more efficient linkage between the builders and users of flight hardware. The identification, development and utilization of advanced technology dramatically lowers instrument, spacecraft, and mission operations costs and contributes to the long-term capability and competitiveness of American industry.

BASIS OF FY 2001 FUNDING REQUIREMENT

CHANDRA X-RAY OBSERVATORY

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Chandra X-ray Observatory development *.........................	45,300	4,100	

* Total cost information is provided in the Special Issues section

PROGRAM GOALS

The Chandra X-ray Observatory (CXO, formerly the Advanced X-ray Astrophysics Facility, AXAF) is the third of NASA's Great Observatories, which include the Hubble Space Telescope and the Compton Gamma Ray Observatory. CXO observes matter at the extremes of temperature, density and energy content. With its unprecedented capabilities in energy coverage, spatial resolution, spectral resolution and sensitivity, CXO is providing unique and crucial information on the nature of objects ranging from nearby stars to quasars at the edge of the observable universe.

STRATEGY FOR ACHIEVING GOALS

The Marshall Space Flight Center (MSFC) was assigned responsibility for managing AXAF in 1978 as a successor to the High Energy Astrophysics Observatory (HEAO) program. The scientific payload was selected through an Announcement of Opportunity (AO) in 1985 and confirmed for flight readiness in 1989.

The AXAF program was restructured in 1992 in response to decreasing future funding projections for NASA programs. The original baseline was an observatory with six mirror pairs, a 15-year mission in low-Earth orbit, and shuttle servicing. The restructuring produced AXAF-I, an observatory with four mirror pairs to be launched into a high-Earth orbit for a five-year lifetime, and AXAF-S, a smaller observatory flying an X-Ray Spectrometer (XRS). A panel from the National Academy of Sciences (NAS) endorsed the restructured AXAF program. The FY 1994 AXAF budget was reduced by Congress, resulting in termination of the AXAF-S mission. The Committees further directed that residual FY 1994 AXAF-S funds be applied towards development of a similar instrument for flight on the Japanese Astro-E mission. Astro-E is scheduled to be launched by Japan in February 2000.

In December 1998 NASA announced that AXAF had been renamed the Chandra X-ray Observatory, in honor of the late Indian-American Nobel laureate, Subrahmanyan Chandrasekhar. CXO was launched successfully by the Space Shuttle and an Inertial Upper Stage on July 23, 1999.

SCHEDULE & OUTPUTS

Launch Observatory Plan: August 1998 Actual: July 23, 1999	Shuttle deployment into low-Earth orbit followed by upper stage delivery to highly elliptical operational orbit. Delayed by need for additional testing and review to ensure mission success.

ACCOMPLISHMENTS AND PLANS

CXO was successfully launched on July 23, 1999. The Observatory has achieved its final science orbit. Launch in July 1999 was an eleven-month slip vs. the original target date. The FY 1999 budget increased by $45.3 million; FY 2000 increased by $4.1 million; adding prior increases of $7.0 million, the total program increase is $56.4 million (about 3.5%).

Following launch, the spacecraft entered a period of checkout, followed by the start of science operations. The observatory is functioning well, and initial results have been very gratifying. Current information is available on the project web site at http://chandra.harvard.edu/index.html.

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE INFRARED TELESCOPE FACILITY

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
SIRTF development *..	119,700	123,400	117,600

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The purpose of the Space Infrared Telescope Facility (SIRTF) mission is to explore the nature of the cosmos through the unique windows available in the infrared portion of the electromagnetic spectrum. These windows allow infrared observations to explore the cold Universe by looking at heat radiation from objects which are too cool to radiate at optical and ultraviolet wavelengths; to explore the hidden Universe by penetrating into dusty regions which are too opaque for exploration in the other spectral bands; and to explore the distant Universe by virtue of the cosmic expansion, which shifts the ultraviolet and visible radiation from distant sources into the infrared spectral region. To exploit these windows requires the full capability of a cryogenically-cooled telescope, limited in sensitivity only by the faint infrared glow of the interplanetary dust.

Rather than simply "descoping" the original Titan-class SIRTF -- the original "Great Observatory" concept -- to fit within a $400 million (FY 1994 constant dollars) cost ceiling imposed by NASA, scientists and engineers have instead redesigned SIRTF from the bottom-up. With an eye towards cost, and in recognition of the unprecedented sensitivity afforded by the latest arrays, the SIRTF Science Working Group identified a handful of the most compelling problems in modern astrophysics for which SIRTF could make unique and important contributions. These primary science themes, which have received the endorsement of the National Research Council's Committee on Astronomy and Astrophysics, satisfy most of the major scientific themes outlined for the original SIRTF mission in the “Bahcall Report” (which judged SIRTF the highest priority major new program for all of U.S. astronomy in the 1990s).

SIRTF is optimized to attack the scientific questions listed below. The first four questions identify the four primary science programs of the SIRTF mission. The fifth question identifies the potential for serendipitous discoveries using SIRTF.

1. How do galaxies form and evolve? SIRTF’s deep surveys will determine how the number and properties of galaxies changed during the earliest epochs of the Universe.

2. What engine drives the most luminous objects in the Universe? SIRTF will study the evolution with cosmic time of the ultraluminous galaxies and quasar populations and probe their interior regions to study the character of their energy sources.

3. Is the mass of the Galaxy hidden in sub-stellar objects and giant planets? SIRTF will search for cold objects with mass less than 0.08 that of the Sun, not massive enough to ignite nuclear reactions, which may contain a significant fraction of the mass of the Galaxy.

4. Have planetary systems formed around nearby stars? SIRTF will determine the structure and composition of disks of material around nearby stars whose very presence implies that these stars may harbor planetary systems.

5. What lies beyond? SIRTF's greater than 1000-fold gain in astronomical capability beyond that provided by previous infrared facilities gives this mission enormous potential for the discovery of new phenomena.

While these scientific objectives drive the mission design, SIRTF's powerful capabilities have the potential to address a wide range of other astronomical investigations. SIRTF should be able to achieve many of the initial goals of the Origins program; SIRTF's measurements of the density and opaqueness of the dust disks around nearby planets will help set the requirements for future Origins missions designed to directly detect planets.

STRATEGY FOR ACHIEVING GOALS

The Jet Propulsion Laboratory (JPL) was assigned responsibility for managing the SIRTF project. The SIRTF Mission is composed of six major system elements and components as described below. The first three elements (the Science Instruments, Cryo/Telescope Assembly, and Spacecraft Assembly) will be assembled into a single space-based observatory system by means of the fourth element -- System Integration and Test. The fifth element is the launch vehicle, and the sixth is the ground system, which will be used to operate the Observatory on the ground prior to launch, and in space, to achieve the mission objectives.

Science Instruments are being provided by three Principal Investigators (PIs) selected by NASA in 1984 in response to a NASA Announcement of Opportunity. The three science instruments and their PIs are: the Infrared Array Camera (IRAC), Smithsonian Astrophysical Observatory, Dr. Giovanni Fazio; the Infrared Spectrometer (IRS), Cornell University, Dr. James Houck; and the Multiband Imaging Photometer for SIRTF (MIPS), University of Arizona, Dr. George Rieke.

The Cryo/Telescope Assembly (CTA) is being developed by Ball Aerospace and Technologies Corporation, Boulder, CO, as an industrial member of the SIRTF Integrated Project Team. The CTA consists of all of the elements of SIRTF that will operate in space at reduced or cryogenic temperatures, including the telescope, telescope cover, cryostat, and supporting structures and baffles. The cryostat contains the cold portions of the PI-provided Science Instruments.

The Spacecraft Assembly is being developed by Lockheed Martin Missiles and Space, Sunnyvale, CA, as an industrial member of the SIRTF Integrated Project Team. The spacecraft assembly consists of all of the elements of SIRTF that are needed for power, data collection, Observatory control and pointing, and communications. These elements of SIRTF are nominally operated at or near 300 degrees Kelvin, and also include the warm portions of the PI-provided Science Instruments.

System Integration and Test (SIT) has been identified as a separate system element, and is being provided by Lockheed Martin Missiles and Space, Sunnyvale, CA, as an industrial member of the SIRTF Integrated Project Team. This element will complete the assembly of the Observatory using the science instruments, the CTA, and the Spacecraft Assembly. System level verification and testing, launch preparations and launch of SIRTF will be performed by this element.

Flight and Science and Operations System development is being accomplished in parallel with Observatory development. This has been done to reduce redundant development of ground equipment and software and to assure compatibility between the ground systems and the Observatory after launch. The Flight Operations segment (FOS) is being developed by the mission development team at JPL. The Science Operations Segment (SOS) is being developed by the SIRTF Science Center located at California Institute of Technology's (Cal Tech) Infrared Processing Analysis Center (IPAC).

SIRTF is planned for launch on a Delta 7925-H launch vehicle in December 2001.

SCHEDULE & OUTPUTS

Instrument Development Plan: April 2000	Deliver the Infrared Array Camera (IRAC), Multiband Imaging Photometer (MIPS), and Infrared Spectrograph (IRS) instruments. The instruments will perform at their specification levels at delivery.
Complete Spacecraft Plan: 2nd Qtr, FY 2001	Complete the SIRTF Spacecraft and have it ready for integration with Cryogenic Telescope Assembly (CTA).
Complete CTA Plan: 2nd Qtr, FY 2001	Complete the SIRTF Cryogenic Telescope Assembly (CTA), and deliver it to spacecraft contractor for integration with spacecraft.

ACCOMPLISHMENTS AND PLANS

SIRTF completed its spacecraft bus structure on schedule in May 1999. Delivery of all of the instrument focal plane arrays was completed on schedule in September 1999. The flight model of the cryostat was completed on schedule in October 1999. Delivery of the instruments will be completed by April 2000 to enable integration of the Cryo/Telescope Assembly late in the fiscal year. The spacecraft and the CTA will be completed and ready for integration in the second quarter of FY 2001.

BASIS OF FY 2001 FUNDING REQUIREMENT

HUBBLE SPACE TELESCOPE DEVELOPMENT

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Hubble Space Telescope Development.................................	159,600	160,100	168,100

PROGRAM GOALS

The goal of the Hubble Space Telescope (HST) development activity is to provide new flight hardware, subsystems, and instruments to extend the telescope's operational life and to enhance its capabilities. HST was launched in April 1990 aboard the Space Shuttle. It is the first and flagship mission of NASA's Great Observatories program, and it is designed to complement the wavelength capabilities of the other spacecraft in the program (CGRO, CXO, and SIRTF). HST is the only one of those observatories that can be serviced and upgraded on orbit. HST is a 2.4-meter telescope capable of performing observations at visible, near-ultraviolet, and near-infrared wavelengths. This program is a joint endeavor of NASA and the European Space Agency (ESA), which provided the faint object camera and the HST's solar arrays. HST is a general observer facility with a worldwide user community.

STRATEGY FOR ACHIEVING GOALS

HST was designed to be serviceable and requires on-orbit maintenance and replacement of spacecraft subsystems and scientific instruments about every three years. Ongoing modification and upkeep of system ground operations are also performed. HST was designed for a minimum 15-year mission; current plans call for the final servicing mission to occur around 2003, and for the spacecraft to operate beyond that time until around the year 2010 or until it fails.

The mission was troubled soon after launch by the discovery that the primary mirror was spherically aberrated. In addition, problems with the solar panels flexing as the spacecraft passed from the Earth's shadow into sunlight caused problems with the pointing stability. These problems limited HST's capabilities, but it still took observations and generated many scientific discoveries prior to the correction of those problems during the First Servicing Mission in December 1993. That mission included replacement of the solar panels, replacement of the Wide Field and Planetary Camera with a second-generation version with built-in corrective optics, and replacement of the High-Speed Photometer with COSTAR (Corrective Optics Space Telescope Axial Replacement) to correct the aberration for the remaining instruments. The mission was a complete success.

The Second HST Servicing Mission occurred in February 1997. The crew accomplished the following tasks: replaced a failed Fine Guidance Sensor (FGS); swapped one of the reel-to-reel tape recorders with a solid-state recorder; and exchanged two of the original instruments (the Goddard High-Resolution Spectrograph and the Faint Object Spectrograph) with two new instruments, the Space Telescope Imaging Spectrograph (STIS) and the Near Infrared Camera and Multi-Object Spectrometer (NICMOS). In addition to this planned work, astronauts discovered that some of the insulation around the light shield portion of the telescope had degraded and they attached several thermal insulation blankets to correct the problem.

The Third HST Servicing Mission, previously scheduled for May 2000, has been split into two missions: Servicing Missions 3A and 3B. Servicing Mission 3A in December 1999 successfully replaced portions of HST's pointing system, flight computer, and other components. Servicing Mission 3B in 2001 will install the new Advanced Camera for Surveys (ACS) science instrument, a new set of solar arrays, a cooling system to extend the life of the Near Infrared Camera / Multi-Object Spectrometer (NICMOS) instrument, and make other repairs.

The fourth HST Servicing Mission (SM-4) is tentatively scheduled for 2003. Although plans for SM-4 are very preliminary at this time, two science instruments are scheduled for installation. The Cosmic Origins Spectrograph (COS) is a medium resolution spectrograph specifically designed to observe into the near and mid ultraviolet. The ultraviolet region is particularly interesting for observing high energy activities such as are found in new hot stars and Quasi Stellar Objects (QSO's). The Wide Field Camera Three (WFC3) will be HST's last main imaging camera. WFC3 will be a replacement for WF/PC-2 to maintain the quality of imaging capabilities throughout the life of the HST mission.

Following SM-4, HST will continue to operate until 2010, or until subsystem failures render the Observatory inoperable.

SCHEDULE & OUTPUTS

Observatory Upgrades/SM-3 Plan: May 2000 Actual/Revised: December 1999 & July 2001	The third Servicing Mission (SM) was split into two missions, SM-3A in December 1999, and SM-3B by July 2001.
HST SM-3A Plan: October 1999 Actual: December 1999	The third Servicing Mission (SM) was split into two missions, SM-3A in December 1999, and SM-3B by July 2001. SM-3A replaced all six gyroscopes, the spacecraft computer, and other hardware items.
HST SM-3B Plan: July 2001	Install two key HST upgrades on Servicing Mission 3B: Advanced Camera for Surveys (ACS) and Solar Array 3 (SA3).

ACCOMPLISHMENTS AND PLANS

HST Servicing Mission 3A was successfully completed, and HST has returned to science operations at the forefront of astronomical research. All plans for Servicing Mission 3B are on track, with the mission currently scheduled for May 2001. Testing of the Advanced Camera for Surveys (ACS) science instrument, the replacement solar arrays, and other components is ongoing. Deliveries of completed units to GSFC for final testing will begin in the latter half of FY 2000.

In preparing for SM4, the initial design, fabrication and assembly of the COS will be completed early in 2000, after which it will enter a period of integration and testing extending through FY 2001. WFC3 initial design, fabrication and assembly have begun, and are expected to continue through late FY 2001. The mission is currently scheduled for June 2003.

BASIS OF FY 2001 FUNDING REQUIREMENT

RELATIVITY MISSION

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
GP-B Development *...	61,300	49,900	13,800

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The purpose of the Relativity Mission (also known as Gravity Probe-B) is to verify Einstein's theory of general relativity. This is the most accepted theory of gravitation and of the large-scale structure of the Universe. General relativity is a cornerstone of our understanding of the physical world, and consequently of our interpretation of observed phenomena. However, it has only been tested through astronomical observation and Earth-based experiments. An experiment is needed to explore more precisely the predictions of the theory in two areas: (1) a measurement of the "dragging of space" by rotating matter; and (2) a measurement of space-time curvature known as the "geodetic effect". The dragging of space has never been measured, and the geodetic effect needs to be measured more precisely. Whether the experiment confirms or contradicts Einstein's theory, its results will be of the highest scientific importance. The measurements of both the frame dragging and geodetic effects will allow Einstein's Theory to be either rejected or given greater credence. The effect of invalidating Einstein's theory would be profound, and would call for major revisions of our concepts of physics and cosmology.

In addition, the Relativity Mission is contributing to the development of cutting-edge space technologies that are also applicable to future space science missions and transportation systems.

STRATEGY FOR ACHIEVING GOALS

This test of the general theory requires advanced applications in superconductivity, magnetic shielding, precision manufacturing, spacecraft control mechanisms, and cryogenics. The Relativity Mission spacecraft will employ super-precise quartz gyroscopes (small quartz spheres machined to an atomic level of smoothness) coated with a super-thin film of superconducting material (needed to be able to "read-out" changes in the direction of spin of the gyros). The gyros will be encased in an ultra-low magnetic-shielded, supercooled environment (requiring complex hardware consisting of lead-shielding, a dewar containing supercooled helium, and a sophisticated interface among the instrument's telescope, the shielded instrument probe, and the dewar). The system will maintain a level of instantaneous pointing accuracy of 20 milliarcseconds (requiring precise star-tracking, a "drag free" spacecraft control system, and micro-precision thrusters). The combination of these technologies will enable the Relativity Mission to measure: (1) the distortion caused by the movement of the Earth's gravitational field as the Earth rotates west to east; and, (2) the distortion caused by the movement of the Relativity Mission spacecraft through the Earth's gravitational field south to north, to a level of precision of 0.5 milliarcsecond per year (the width of a human hair observed from 16 miles).

The expertise to design, build and test the Relativity Mission, as well as the detailed understanding of the requirements for the dewar and spacecraft, resides at Stanford University in Palo Alto, CA. Consequently, MSFC has assigned responsibility for experiment management, design, and hardware performance to Stanford. Science experiment hardware development (probe, gyros, dewar, etc.) and spacecraft development are conducted at Stanford in collaboration with Lockheed Martin Missiles and Space Palo Alto Research Laboratory (LPARL). Spacecraft development and systems integration are being performed by Lockheed Martin Missiles and Space. Launch is scheduled for September 2001 aboard a Delta II launch vehicle.

SCHEDULE & OUTPUTS

Flight Probe integrated with Science Instrument Assembly Plan: April 1998 Actual: July 1999	Successful integration of the science instrument (comprised of gyroscopes, telescopes, detection electronics, and gas management) with the probe. Schedule delays have resulted from technical problems in various science instruments and subsystems, especially during detector package assembly and acceptance testing of the flight gyroscopes.
Flight Telescope Delivery Plan: February 1998 Actual: February 1999	Delivery of the custom, fused-quartz star tracking telescope. Schedule was delayed principally by numerous development problems with the Detector Package Assembly.
Payload Flight Verification Plan: February 1999 Revised: July 2000	Complete the payload (dewar, science instrument, and probe) testing and verification. Schedule delay is driven by the need to repair the probe and repeat testing and verification.
Spacecraft Design, Fab, Assy, and Test Plan: March 1999 Revised: June 2000	Complete the spacecraft design, fabrication, assembly, and test. Work has been deliberately slowed to allow more resources to be applied to the payload.
Final integration and test Plan: March 2000 Revised: September 2000 Revised: July 2001	Complete final integration and test of the Gravity Probe-B science payload with the spacecraft. The final integration date has been delayed due to the need to repair the probe after a failure occurred during payload testing
Launch Plan: March 2000 Revised: October 2000 Revised: September 2001	Successful launch and check-out. Launch has been delayed due to development problems cited above.

ACCOMPLISHMENTS AND PLANS

Gravity Probe-B is proceeding toward a September 2001 launch date. The program had previously been attempting to achieve an earlier launch date, but a failure in the flight probe discovered during payload flight verification has eliminated that possibility. The spacecraft is manifested to launch aboard a Delta II. Accomplishments in FY 1999 included completion of the flight telescope in February 1999. Integration of the science instrument was completed in June 1999. Installation of the science instrument in the flight probe was completed in July 1999, and installation of the flight probe into the dewar was completed in August 1999.

In FY 2000, the program expects to repair the flight probe, reinstall the flight probe into the flight dewar, complete payload flight verification testing, and deliver the payload for integration with the spacecraft.

We are expecting a significant cost growth in FY 2001 as a result of the delay from the baseline launch in October 2000 to September 2001. The cost growth is driven by schedule and manpower needs associated with resolving the technical issues that caused the delay. To prevent or mitigate further schedule delays, resources have been shifted from the spacecraft effort, which is well ahead of critical path, to the probe repair and payload integration and test efforts, which are on the critical path. Civil service on-site presence at Stanford has been significantly increased, as has involvement by the External Independent Readiness Review, the GP-B Science Advisory Committee, and the GP-B Dewar Council. NASA is continuing to review Relativity Mission funding requirements and will notify Congress of funding changes as soon as the information becomes available.

BASIS OF FY 2001 FUNDING REQUIREMENT

THERMOSPHERE, IONOSPHERE, MESOSPHERE ENERGETICS AND DYNAMICS (TIMED)

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
TIMED Development *..	53,300	27,500	

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The primary objective of the TIMED mission is to investigate the energetics of the Mesosphere and Lower Thermosphere/Ionosphere (MLTI) region of the Earth's atmosphere (60-180 km altitude). The MLTI is a region of transition in which many important processes change dramatically. It is a region where energetic solar radiation is absorbed, energy input from the aurora maximizes, intense electrical currents flow, and atmospheric waves and tides occur; and yet, this region has never been the subject of a comprehensive, long-term, global investigation. TIMED will provide a core subset of measurements defining the basic states (density, pressure, temperature, winds) of the MLTI region and its thermal balance for the first time. These measurements will be important for developing an understanding of the basic processes involved in the energy distribution of this region and the impact of natural and anthropogenic variations. In a society increasingly dependent upon satellite technology and communications, it is vital to understand the atmospheric variabilities so that the impact of these changes on tracking, spacecraft lifetimes, degradation of materials, and re-entry of piloted vehicles can be predicted. The mesosphere may also show evidence of anthropogenic effects that could herald global-scale environmental changes. TIMED will characterize this region to establish a baseline for future investigations of global change.

STRATEGY FOR ACHIEVING GOALS

The TIMED mission is the first science mission in a planned program of Solar Terrestrial Probes (STP), as detailed in the Space Science Strategic Plan. TIMED is part of NASA's initiative aimed at providing cost-efficient scientific investigations and more frequent access to space. TIMED is being developed for NASA by the Johns Hopkins University Applied Physics Laboratory (APL). The Aerospace Corporation, the University of Michigan, NASA's Langley Research Center with the Utah State University's Space Dynamics Laboratory, and the University of Colorado are providing instruments for the TIMED mission.

TIMED is on schedule and ready for launch in May 2000 aboard a Delta II launch vehicle co-manifested with JASON, an Earth Science mission. However, due to Jason's inability to meet the May launch date, the TIMED spacecraft is now scheduled for a fall 2000 launch. The program began its 36-month Phase C/D development period in April 1997. TIMED will be a single spacecraft located in a high-inclination, low-Earth orbit with instrumentation to remotely sense the mesosphere/lower thermosphere/ionosphere regions of the Earth's atmosphere. TIMED carries four instruments: the Solar Extreme ultraviolet Experiment (SEE), the Sounding of Atmospheric using Broadband Emission Radiometry (SABER) infrared sounder, the Global Ultraviolet Imager (GUVI) and the TIMED Doppler Interferometer (TIDI).

SCHEDULE & OUTPUTS

Begin Spacecraft I&T Plan: January 1999 Actual: September 1998	Spacecraft integration and test began ahead of schedule and is expected to end January 2000.
Completion of Instrument Development Plan: June 1999 Actual: August 1999	Complete delivery of all 4 flight instruments to APL.
Launch Plan: May 2000 Revised: Fall 2000	TIMED will be delivered on time for launch in May 2000 aboard a Delta II launch vehicle co-manifested with JASON, an Earth Science mission, and will be completed within 10% of the planned development budget. However, due to Jason's inability to meet the May launch date, the TIMED spacecraft is now scheduled for a fall 2000 launch

ACCOMPLISHMENTS AND PLANS

Spacecraft development was completed in FY 1999. All of the instruments were delivered by September 1999. TIMED will be completed in early 2000 and will be put in storage from March 2000 through July 2000 with launch scheduled for the fall of 2000 due to launch delays in co-manifested Jason spacecraft.

BASIS OF FY 2001 FUNDING REQUIREMENT

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Stratospheric Observatory for Infrared Astronomy.............	51,200	39,000	33,900
[Construction of Facilities]	[7,000]		

PROGRAM GOALS

The primary objective of the SOFIA program is to make fundamental scientific discoveries and contribute to our understanding of the universe through gathering and rigorous analysis and distribution of unique infrared astrophysical data. This will be accomplished by extending the range of astrophysical observations significantly beyond that of previous infrared airborne observatories through increases in sensitivity and resolution.

While accomplishing its scientific mission, the SOFIA program will make significant and measurable contributions in meeting national goals for the reform of science, mathematics, and technology education, particularly at the K-16 level, and in the general elevation of scientific and technological literacy throughout the country. In addition, the SOFIA program will identify, develop, and infuse promising new technologies, which will enable or enhance scientific or educational objectives and reduce mission life-cycle costs.

STRATEGY FOR ACHIEVING GOALS

Astronomical research with instrumented jet aircraft has been an integral part of the NASA Physics and Astronomy program since 1965. For relatively low cost, NASA has been able to provide to the science community very quick, global response to astronomical "targets of opportunity." The Stratospheric Observatory For Infrared Astronomy (SOFIA) is a new airborne observatory designed to replace the retired Kuiper Airborne Observatory (KAO). SOFIA consists of a 2.5 m telescope provided by the German Aerospace Center (DLR) integrated into a modified Boeing 747 aircraft. With spatial resolution and sensitivity far superior to the KAO, SOFIA will facilitate significant advances in the study of a wide variety of astronomical objects. The program will build upon a very successful program of flying teachers on the KAO, by using SOFIA to reach out to K-12 teachers as well as science museums and planetaria around the country.

KAO operations were terminated in October 1995; the savings from cessation of KAO operations are an integral element of the funding plan for SOFIA. Development of SOFIA started in FY 1997. In December 1996, NASA selected a team led by the Universities Space Research Association (USRA), Columbia, MD to acquire, develop and operate SOFIA. The Cost-Plus-Incentive and Award Fee-type contract has a base period for development plus one five-year operations cycle. The contract also contains an option period for one additional five-year operations cycle. SOFIA is expected to operate for at least 20 years. The contract is managed by NASA's Ames Research Center, Mountain View, CA. Other team members include Raytheon Systems Company - Waco, TX; United Airlines, San Francisco; an alliance of the Astronomical Society of the Pacific and The SETI Institute, both of Mountain View, CA; Sterling Software, Redwood City, CA; and the University of California at Berkeley and Los Angeles. The contract called for the selected company to acquire an existing Boeing 747 SP aircraft, design and implement a modification program to accommodate installation of a large infrared telescope (provided by Germany), test and deliver the flying astronomical observatory to NASA, and provide mission and operations support in approximately five-year increments. USRA's proposal called for operating the aircraft out of Moffett Federal Airfield, Mountain View, CA. SOFIA funding includes $7.0 million in FY 1999 Construction of Facilities funds for modification of SOFIA ground support facilities at the Ames Research Center.

SCHEDULE & OUTPUTS

Telescope Assembly Critical Design Review Plan: November 1998 Revised: April 2000	Formal review of the German contractor's concept for implementation of the telescope assembly. Slipped due to delays in the development of the German telescope assembly.
US System Critical Design Review Plan: September 1999 Revised: June 2000	Formal review of the US concept for implementation of the observatory. Slipped due to delays in the development of the German telescope assembly
Install Cavity Door on Fuselage Mockup Plan: 1st Qtr., FY 2001	Complete the installation of the flight cavity door on the 747 SP fuselage mockup with no anomalies that would require redesign.
Complete the 747 Section 46 Mockup Test Activity Plan: June 2000 Revised: 2nd Qtr., FY 2001	Subject to replanning activities, it is anticipated that the U.S. systems CDR will be completed, the fuselage section mockup pathfinder work will be completed, and major aspects of the structural modification of the 747 SP will be underway.
Complete 747 Structural Modification Plan: FY 2001	Complete structural modification of the 747 SP.
Initial Science Flight Plan: November 2002	Initial operational science flight of the observatory. Delayed from initial target date of October 2001 due to delays in German telescope assembly.

ACCOMPLISHMENTS AND PLANS

In FY 1999, substantial progress was made. The U.S. and German PDRs were completed, as were wind tunnel testing and aerodynamic analysis of the modified aircraft. The 747 fuselage section mockup structural modification was completed, paving the way for the start of the fuselage modification on the SOFIA 747 SP. Fabrication of several key telescope elements took place in Germany. Of particular note, the German primary mirror fabrication and lightweighting was completed, reducing the mass of the mirror by 75%.

Also, modifications of the hangar at Moffett Field, CA began in FY 1999. This hangar will ultimately become the SOFIA Science and Mission Operations Center, serving as the “home” for the SOFIA Observatory once it enters science operations.

A major task accomplished in FY 1999 was the re-planning of the overall program, incorporating the delay in the planned delivery of the German telescope.

In FY 2000, the German Telescope Assembly and U.S. systems critical design reviews (CDRs) will be completed, and major aspects of the structural modification of the 747 SP will be underway. Our German partners should also be far along in the fabrication and test of all major elements of the Telescope Assembly.

In FY 2001, it is anticipated that the structural modification of the 747 SP will be completed. In Germany, all elements of the Telescope Assembly hardware should complete fabrication and subsystem testing, in preparation for installation into the SOFIA 747 SP early in FY 2002, at which point overall Observatory-level integration, test, and verification will commence. Initial SOFIA science operations are now planned to start in November 2002.

BASIS OF FY 2001 FUNDING REQUIREMENT

PAYLOAD AND INSTRUMENT DEVELOPMENT

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Astro-E	6,400		
Rosetta	12,500	6,100	1,400
Cluster-II	5,000	1,000	
Shuttle/International payloads	5,000	6,000	5,200
Spartan	300	500	500
Total	29,200	13,600	7,100

PROGRAM GOALS

Payload and Instrument Development supports development of hardware to be used on international satellites or on Shuttle missions. International collaborative programs offer opportunities to leverage U.S. investments, obtaining scientific data at a relatively low cost. Shuttle missions utilize the unique capabilities of the Shuttle to perform scientific experiments that do not require the extended operations provided by free-flying spacecraft. Payload and Instrument Development supports investigations in the Astronomical Search for Origins, Sun-Earth Connections, Structure and Evolution of the Universe, and Exploration of the Solar System science themes.

STRATEGY FOR ACHIEVING GOALS

In the FY 1994 appropriation, Congress directed NASA to pursue flight of a GSFC-developed X-ray spectrometer on the Japanese Astro-E mission. NASA contributed improved foil mirrors and an X-ray calorimeter derived from the spectrometer previously planned for the canceled AXAF-S mission. This new device will measure the energy of an incoming X-ray photon by precisely measuring the increase in temperature of the detector as the photon is absorbed. The foil mirrors will have a large collecting area, providing approximately 2 arc second resolution. These capabilities will permit an unprecedented study of a wide range of astrophysical sources. Launch is scheduled for February 2000.

The European Space Agency's ROSETTA mission is a cometary mission that will be launched in the year 2003 by an Ariane 5. The satellite will rendezvous with comet Wirtanen, in late 2011, and orbit it while taking scientific measurements. During the cruise phase, the satellite will be given gravity assist maneuvers once by Mars and twice by the Earth. The satellite will also take measurements during fly-bys of two asteroids. U.S involvement in the Rosetta program includes the development of three remote sensing instruments, as well as support for interdisciplinary scientists and a number of U.S. co-investigators.

The Shuttle/International Payloads program supports other international and U.S. development projects, including portions of two instruments flown on Europe's X-ray Mirror Mission (XMM, December 1999); and participation in Europe's International Gamma

Ray Astrophysics Laboratory (INTEGRAL, 2001) and Planck (approx. 2007) missions, as well as the instrument and components for the Cluster-II mission

The original Cluster mission, part of the International Solar-Terrestrial Physics program, was lost on June 4, 1996 with the explosion of the Ariane-5 rocket. Reflight of the full mission (Cluster-II) has been approved by the European Space Agency and NASA. The four spacecraft will carry out three-dimensional measurements in the Earth's magnetosphere, covering both large- and small-scale phenomena in the sunward and tail regions. Launch is scheduled for June 2000 on two Soyuz vehicles.

The ESA XMM satellite has highly sensitive instruments providing broad-band study of the X-ray spectrum. This mission combines telescopes with grazing incidence mirrors and a focal length greater than 7.5 meters with three imaging array instruments and two Reflection Grating Spectrometers (RGS). The U.S. has provided components to the Optical Monitor (OM) and RGS instruments. XMM science is complementary to the U.S. Chandra X-ray Observatory (CXO). XMM's higher through-put (i.e., higher number of photons collected) will allow somewhat better spectroscopy of faint sources, while CXO will excel at high resolution imaging. XMM was launched December 10^{th} 1999 on an Ariane-5 vehicle.

The ESA INTEGRAL mission will perform detailed follow-on spectroscopic and imaging studies of objects initially explored by the Compton Gamma Ray Observatory. Its enhanced spectral resolution and spatial resolution in the nuclear line region will provide a unique channel for the investigation of processes -- nuclear transitions, electron/positron annihilation, and cyclotron emission/absorption -- taking place under extreme conditions of density, temperature, and magnetic field. U.S. participation consists of co-investigators providing hardware and software components to the spectrometer and imager instruments; a co-investigator for the data center; a mission scientist; and a provision for ground tracking and data collection. Launch is expected in FY 2001.

Planck is the third Medium-Sized Mission (M3) of ESA's Horizon 2000 Scientific Program. It is designed to image the anisotropies of the Cosmic Background Radiation Field over the whole sky, with unprecedented sensitivity and angular resolution. Planck will help resolve several cosmological and astrophysical issues by verifying or refuting the assumptions underlying competing theories of the early universe and the origin of cosmic structure. Planck is expected to be launched with the FIRST satellite but will separate and be placed in a different orbit around the second Lagrangian point of the Earth-Sun System. Although formal agreements have not been finalized, NASA expects to contribute hardware elements for the mission in exchange for science participation.

The Spartan program provides reusable spacecraft, which can be flown aboard the Shuttle. These units can be adapted to support a variety of science payloads and are deployed from the Shuttle cargo bay to conduct experiments for a short time (i.e. several hours or days). Payloads are later retrieved, reinstalled into the cargo bay and returned to Earth. The science payload is returned to the mission scientists for data retrieval and possible refurbishment for a future flight opportunity. The Spartan carrier is also refurbished and modified as needed to accommodate the next science payload.

SCHEDULE & OUTPUTS

Astro-E:	
Flight Model Spectrometer Delivery to Japan Plan: July 1997 Actual: January 1999	This task concluded the XRS instrument construction phase and started a period of validation, testing and calibration. This task was completed late, with subcomponents delivered to Japan as completed. Late deliveries have been accommodated by the Japanese within their schedule.
Final Mirror Quadrant Delivery Plan: December 1998 Actual: April 1999	Satisfied NASA's commitment to provide the X-ray mirrors for the mission to Japan. mirrors perform within specification.
Rosetta:	
Start Phase C/D Plan: January 1999 Actual: January 1999	Start of detailed design and fabrication.
Qualification Model Deliveries Plan: May 2000	Deliver the electrical qualification models for the four U.S.-provided instruments to ESA in May 2000 for integration with the Rosetta Orbiter.
Flight Unit Deliveries Plan: 3rd Qtr., FY 2001	Deliver the flight units for the four U.S.-provided instruments or instrument subsystems to ESA.
Cluster-II:	
4th/final flight model instrument set delivered Plan: August 1999 Actual: September 1999	All U.S. hardware was delivered and completed by September 1999.
Instrument Analysis Software and Verification Plan: FY 2000	Complete the development of the Cluster-II instrument analysis software for the one U.S. and five U.S.-partnered instruments before launch and, if launch occurs in FY00, activate and verify the wideband data and U.S. subcomponents after launch.

Other Shuttle/International:

XMM Launch Plan: August 1999 Revised: January 2000 Actual: December 10, 1999	Launched successfully by ESA on Ariane-5 ELV.
INTEGRAL Critical Design Review Plan: June 1999 Actual: December 1999	This ESA program review included the U.S.-provided hardware.
INTEGRAL Operations Readiness Plan: FY 2000	Prepare the INTEGRAL Science Data Center (ISDC) for data archiving and prepare instrument analysis software for the Spectrometer on INTEGRAL (SPI) instrument.
Planck Cooler Test Plan: April 2000	Assemble and successfully test the breadboard cooler for ESA's Planck mission.
Planck Cooler Performance Report Plan: 4th Qtr., FY 2001	Deliver the Preliminary Breadboard Cooler Performance Report.

ACCOMPLISHMENTS AND PLANS

The first quadrant of flight model mirrors for Astro-E was delivered to Japan in December 1997, and the final quadrant was delivered in April 1999. The science instrument hardware has experienced serious technical difficulties and delays, resulting in a slight overrun (about 3% to date). The project is still on schedule for a February 2000 launch. All hardware has been delivered and integration is complete. We continue to work with our Japanese partners to ensure a successful mission.

Implementation of the U.S. Rosetta instruments began in January 1999. Structural-thermal models were delivered at the end of June 1999. The electrical qualification models are being delivered in February 2000, followed by the flight models in January 2001.

Cluster II instrument development activities have progressed very well. Deliveries of the 2nd, 3rd, and 4th Cluster-II flight model sets occurred throughout FY 1999, supporting ESA's June 15, 2000 launch date. All US hardware deliveries were completed on time and within budget.

XMM Flight Model-2 RGS components were delivered to Germany ahead of schedule in March 1998. The U.S. supported integration of instruments onto the spacecraft, and spacecraft integration with the launch vehicle. XMM was successfully launched in December 1999 and has begun orbital operations.

INTEGRAL engineering model instruments were delivered to ESTEC on schedule in May 1998. Work on the flight model will continue through first two quarters of FY 2000; Flight Model delivery is expected February 15, 2000.

Spartan continues as an advanced carrier, which could support Explorer missions, environmental science initiatives, as well as Space Station free-flyers.

EXPLORER PROGRAM

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Far Ultraviolet Spectroscopy Explorer................................	14,600		
Submillimeter Wave Astronomy Satellite, Transition Region and Coronal Explorer, Wide-field Infrared Explorer...................	7,800		
Imager for Magnetopause-to-Aurora Global Exploration & Microwave Anisotropy Probe	90,200	34,100	15,100
Student Explorer Demonstration Initiative	3,600	5,000	2,700
High Energy Transient Explorer-II	11,100	3,200	
High Energy Solar Spectroscopic Imager	30,700	20,400	
Galaxy Evolution Explorer	25,500	17,400	17,900
Two Wide-Angle Neutral-Atom Spectrometers	4,700	3,600	1,600
Cosmic Hot Interstellar Plasma Spectrometer	4,100	5,400	3,200
Inner Magnetosphere Explorer	6,000	4,900	2,600
Explorer Planning (All Others)	6,800	28,300	95,700
*Total	205,100	122,300	138,800

*Total cost information is provided in the Special Issues section.

PROGRAM GOALS

The goal of the Explorer Program is to accomplish frequent, high-quality space science investigations utilizing innovative, streamlined, and efficient management approaches. It seeks to substantially reduce mission cost through commitment to, and control of, design, development, and operations costs, as well as to reduce cost and improve performance through the use of new technology. Finally, it seeks to enhance public awareness of, and appreciation for, space science and to incorporate educational and public outreach activities as integral parts of space science investigations. Investigations selected for Explorer projects are usually of a survey nature, or have specific objectives not requiring the capabilities of a major observatory. The Explorers Program develops scientific missions of modest programmatic scope within the following space science themes: Astronomical Search for Origins and Planetary Systems, The Sun-Earth Connection, and Structure and Evolution of the Universe.

STRATEGY FOR ACHIEVING GOALS

Explorer mission development is managed within an essentially level funding profile. New missions are, therefore, subject to the availability of sufficient funding in order to stay within the total program budget. Explorer missions are categorized by size, starting with the largest, Delta-class, moving down through the Medium-class (MIDEX), the Small-class (SMEX) and the University-class (UNEX) missions. Funding for Explorer launch services and mission studies is also provided within the Explorer budget.

Delta Class

Development of the Far Ultraviolet Spectroscopy Explorer (FUSE) began early in FY 1996. The FUSE mission, previously planned as the last of the Delta-class missions, was restructured in order to reduce costs and accelerate the launch date from CY 2000 to early CY 1999. Although not a MIDEX mission, FUSE can be seen as a transitional step towards the MIDEX program. The FUSE mission is to conduct high-resolution spectroscopy in the far ultraviolet region. Major participants include the Johns Hopkins University, the University of Colorado, and University of California, Berkeley. Orbital Sciences Corporation was selected by JHU as the spacecraft developer. Canada provided the fine error sensor assembly, and France provided holographic gratings. NASA's Goddard Space Flight Center provided management oversight of this Principal Investigator-managed mission. FUSE launched successfully in June 1999 aboard a Delta-II launch vehicle.

Medium Class

The Medium-class Explorer (MIDEX) program was initiated to facilitate more frequent flights, and thus more research opportunities, in all OSS themes. The MIDEX investigations are characterized by a definition, development, launch service, and mission operations and data analysis cost not to exceed $140 million (in Fiscal Year 1998 dollars) total cost to NASA. NASA intends to launch one MIDEX mission per year.

In March 1996 NASA selected the first two science missions for the MIDEX program, the Microwave Anisotropy Probe (MAP) and the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE). The MAP Mission will undertake a detailed investigation of the cosmic microwave background to help understand the large-scale structure of the universe, in which galaxies and clusters of galaxies create enormous walls and voids in the cosmos. GSFC is developing the MAP instruments in cooperation with Princeton University. The IMAGE mission will use three-dimensional imaging techniques to study the global response of the Earth's magnetosphere to variations in the solar wind, the stream of electrified particles flowing out from the Sun. The magnetosphere is the region surrounding the Earth controlled by its magnetic field and containing the Van Allen radiation belts and other energetic charged particles. Southwest Research Institute is developing the IMAGE mission.

In April of 1998 NASA released an Announcement of Opportunity (AO) for MIDEX 3 & 4, and in January 1999 five proposals were selected in the Step-1 selection for detailed four-month feasibility studies. Step-2, or final, selections were made in October 1999, and the Swift Gamma Ray Burst Explorer (Swift) and Full-sky Astrometric Mapping Explorer (FAME) missions have been selected to continue mission formulation activity. The Swift mission, to be launched in the third quarter of FY 2003, is a three-telescope space observatory for studying gamma ray bursts. Dr. Neil Gehrels of NASA's Goddard Space Flight Center will lead the Swift mission. The FAME mission, to be launched in the third quarter of FY 2004, is a space telescope designed to obtain highly precise position and brightness measurements of 40 million stars. Dr. Kenneth J. Johnston of the U.S. Naval Observatory will lead the FAME mission.

Small Class

The Small Explorer (SMEX) program provides frequent flight opportunities for highly focused and relatively inexpensive missions. SMEX investigations are characterized by a total cost to NASA for definition, development, launch service, and mission operations and data analysis not to exceed $71 million (in Fiscal Year 1998 dollars) . It is NASA's intent to launch one Small Explorer mission per year. The Explorer Program Office at GSFC manages mission definition, development, and launch of these SMEX missions.

The Transition Region and Coronal Explorer (TRACE) mission initiated development in October 1994, and launched successfully in April 1998. TRACE is a solar science mission that will explore the connections between fine-scale magnetic fields and their associated plasma structures. The Submillimeter Wave Astronomy Satellite (SWAS) mission initiated development in 1991, and launched successfully in December 1998. The SWAS mission is providing discrete spectral data for study of the water, molecular oxygen, neutral carbon, and carbon monoxide in dense interstellar clouds, the presence of which is related to the formation of stars. The Wide-field Infrared Explorer (WIRE) mission was intended to detect starburst galaxies, ultraluminous galaxies, and luminous protogalaxies. WIRE initiated development in October 1994 and launched in March 1999. However, WIRE could not carry out its intended science objective when its telescope cover ejected prematurely, resulting in the rapid evaporation of the on-board cryogen. WIRE is currently being used as a testbed for technology validation and is making photometric measurements with its precise star trackers.

The High Energy Solar Spectroscopic Imager (HESSI) and the Galaxy Evolution Explorer (GALEX) missions were selected in October 1997 as the next SMEX missions. HESSI will observe the Sun to study particle acceleration and energy release in solar flares. The Galaxy Evolution Explorer (GALEX) is an Ultraviolet Small Explorer mission that will map the global history of the universe through 80 percent of its life. GALEX will probe the causes of star formation during that period in which galaxies evolved dramatically, and most stars, elements, and galaxy disks had their origins. HESSI is being developed by the University of California at Berkeley, and is scheduled for launch on board a Pegasus ELV in July 2000. The GALEX mission is being developed by the California Institute of Technology, with a launch planned for mid-CY 2001.

An Announcement of Opportunity for the next SMEX mission was released in December 1999. A Step-1 selection is planned for 4th Qtr. FY 2000, followed by a Step-2 selection in 3rd Qtr. FY 2001.

Student Explorer Demonstration Initiative and University Class

University-class Explorer (UNEX) missions are ultimately intended to enable a higher flight rate to provide the academic community with routine access to space science research. The UNEX program supports very small, low-cost missions managed, designed and developed at universities, in cooperation with industry. The program will develop greater technical expertise within the academic community beyond the suborbital class missions currently being flown aboard balloons and sounding rockets, thus creating greater opportunity for students and reducing the required role of NASA in-house expertise.

From responses to a UNEX AO released in January 1998, NASA selected Cosmic Hot Interstellar Plasma Spectrometer (CHIPS) and Inner Magnetosphere Explorer (IMEX) in September 1998 as the first set of UNEX missions. CHIPS will use an extreme ultraviolet spectrograph during its one-year mission to study the “Local Bubble,” a tenuous cloud of hot gas surrounding our solar system that extends about 300 light-years from the Sun. CHIPS will be developed by the University of California Berkeley. SpaceDev will build the CHIPS spacecraft. IMEX will study the response of Earth’s Van Allen radiation belts to variations in the solar wind. Participants for the IMEX mission include the University of Minnesota, University of Colorado, and Aerospace Corporation. Implementation of both missions has been delayed due to the unavailability of a small launch vehicle and the difficulties of obtaining secondary payload space on larger vehicles.

The UNEX precursor missions under the Student Explorer Demonstration Initiative (STEDI) include the Student Nitric Oxide Experiment (SNOE), Tomographic Experiment using Radiative Recombinative Ionospheric EUV and Radio Sources (TERRIERS), and

Cooperative Astrophysics and Technology Satellite (CATSAT). SNOE is a small scientific satellite that is measuring the effects of energy from the sun and from the magnetosphere on the density of nitric oxide in the Earth's upper atmosphere. SNOE launched successfully in February 1998, and it is now being operated from the mission operations center at the University of Colorado's LASP Space Technology Research building. TERRIERS launched in May 1999. Unfortunately, the spacecraft's attitude control system did not function properly due to software problems, and the mission is no longer operational. CATSAT development is completed, the spacecraft is in storage, awaiting launch opportunity in July 2001.

MISSIONS OF OPPORTUNITY

Missions of Opportunity (MO) were instituted within the Explorer Program as part of the previously mentioned SMEX AO. MO are space science investigations, costing no more than $21 million in FY1998 dollars, that are flown as part of a non-NASA space mission. MO are conducted on a no exchange of funds basis with the organization sponsoring the mission. OSS intends to solicit proposals for MO with all future Explorer AOs.

Under the 1997 SMEX AO, the Two Wide-Angle Neutral-Atom Spectrometers (TWINS) investigation was selected as a MO. TWINS will enable three-dimensional global visualization of Earth's magnetospheric region, thereby greatly enhancing understanding of the connections between different regions of the magnetosphere and their relation to the solar wind. Instruments for the TWINS mission are being developed by Los Alamos National Laboratory (LANL) for launch in 2003 and 2004.

Development is underway for HETE-II, an international (France, Italy and Japan) collaboration, to be launched in June 2000 from Kwajalein Island. HETE-II will seek to obtain precise positions of gamma-ray bursters and other high-energy transient sources. HETE-II is a replacement for HETE-I, which was lost in November 1996 due to launch vehicle third-stage power failures.

SCHEDULE & OUTPUTS

Far Ultraviolet Spectroscopy Explorer (FUSE)

Ship to KSC Plan: September 1998 Revised: April 1999 Actual: April 1999	Shipped on schedule.
Launch Plan: October 1998 Revised: May 1999 Actual: June 1999	Successfully launched June 1999. All spacecraft and instrument subsystems functioning nominally.

Medium-class Explorer Program

IMAGE

Complete S/C Environmental Testing Plan: April 1999 Actual: April 1999	Integrate and test major spacecraft subsystems. Completed.
Delivery, Launch Plan: February 2000	IMAGE will be delivered for an on-time launch.

MAP

Instrument Delivery Plan: 2nd Qtr. CY 1999 Actual: : 2nd Qtr. CY 1999	Complete instrument development and ship for integration with the spacecraft. Completed.
Begin S/C I&T Plan: 3rd Qtr. CY 1999 Actual: : 3rd Qtr. CY 1999	Integrate and test major spacecraft components. Completed.
Begin Environmental Testing Plan: July 2000	Begin system-level environmental testing of the spacecraft.
Delivery, Launch Plan: 1st Qtr., FY 2001	Deliver MAP for launch.

Small-class Explorer Program

<u>WIRE</u>	
Launch Plan: August 1998 Revised: March 1999 Actual: March 1999	WIRE launched successfully. Mission failed due to the telescope's protective cover being ejected too early, allowing radiation from the Sun to enter the telescope, causing the temperature to rise and the cryogens to boil off. Spacecraft is currently conducting limited science operations using the Star Tracker, and is also being used as a spacecraft control test bed.
<u>HESSI</u>	
Delivery, Launch Plan: July 2000	HESSI will be delivered in time for a planned July 2000 launch
<u>GALEX</u>	
Instrument Delivery Plan: July 2000	Deliver the GALEX science instrument from JPL to the Space Astrophysics Laboratory at Caltech during April 2000 for science calibration. The instrument will be fully integrated, functionally tested, and environmentally qualified at the time of the delivery.
Delivery, Launch Plan: 4th Qtr., FY 2001	Deliver GALEX for launch.
<u>TWINS</u>	
Component Deliveries Plan: March 2000 Revised: 3rd Qtr., FY 2001	Deliver to the Los Alamos National Laboratory in March 2000 all components for system integration and testing of the first flight system for the TWINS mission. The TWINS mission is a payload of opportunity. Scheduled delivery has been delayed to accommodate the schedule of the non-NASA host spacecraft.

<u>University-class Explorer Program</u>

<u>TERRIERS</u>	
Launch Plan: April 1999 Actual: May 1999	TERRIERS launched successfully in May 1999; however, a flight software error (causing the solar array to point away from the sun) has left the mission unable to meet its science objective.
<u>CATSAT</u>	
Launch Plan: 3rd Qtr., FY 1999 Revised: 4th Qtr., FY 2001	Deliver the CATSAT for launch. Delayed due to uncertain launch accommodations.
<u>HETE-II</u>	

Launch Plan: December 1999 Revised: June 2000	Complete HETE-II development and launch spacecraft. Launch is currently planned for June 2000. Launch delay is due to approval required for launches from Kwajalein Island and additional testing to ensure mission success.

AO Activities

MIDEX Selection Plan: 4th Qtr. FY 1999 Actual: January 1999	Mission selection, and initiate concept studies. Step-1 selections made in January 1999, and Step-2 selections, SWIFT and FAME, made in October 1999.
Release SMEX AO to industry Plan: 3rd Qtr FY 1999 Actual: December 2, 1999	Release the final AO to industry. Final released to industry December 2, 1999.
SMEX AO Selection Plan: 1st Qtr FY 2000 Revised: 4th Qtr. FY 2000	Mission selection, leading to concept studies.
SMEX Selection Plan: FY 2001	Down-selection (Step 2) for SMEX 8 and SMEX 9.

ACCOMPLISHMENTS AND PLANS

The Explorers Program launched three missions during FY 1999. The Wide-field Infrared Explorer (WIRE) mission in March 1999, the Tomographic Experiment using Radiative Recombinative Ionospheric EUV and Radio Sources (TERRIERS) in May 1999, and the Far Ultraviolet Spectroscopy Explorer (FUSE) in June 1999. Two of the three missions failed, one due to software problems (TERRIERS), and the other to exhaustion of on-board cryogen (WIRE). Currently, the WIRE mission is being used as a technology testbed by other missions to test flight software and other capabilities. Spacecraft and instrument development for the IMAGE, MAP, HESSI and GALEX missions continued throughout FY 1999. CHIPS completed Phase A, and entered Phase B in September 1999. In September 1998 IMEX entered phase A, which was continued throughout FY99 due to launch vehicle unavailablity. Five MIDEX proposals were selected for Phase A studies in January 1999. CATSAT has completed development, and the spacecraft is in storage awaiting launch opportunity.

The FY 2000 Explorer budget continues to support a full range of mission activities across the various classes of missions. Three missions are targeted for launch in fiscal year 2000: HETE-II in June 2000, IMAGE in February 2000, and HESSI in July 2000. The following activities should be completed during FY 2000 for MAP: spacecraft component and instrument development, subsystem-level testing, and shipment to launch site. SWIFT and FAME were selected as MIDEX-3 and 4 missions in October 1999, and are expected to complete the formulation phase and enter into implementation phase during FY 2000. The GALEX science instrument will be delivered from Jet Propulsion Laboratory (JPL) to the California Institute of Technology for integration and test. An Announcement of Opportunity (AO) for the next SMEX missions was released in December 1999, Step 1 selections will be made in the 4th Quarter of FY 2000. Mission studies and spacecraft and instrument development for the CHIPS and IMEX missions will continue through FY 2000. Missions of Opportunity (MO) include a launch for High Energy Transient Explorer (HETE)-II and continued development of the Two Wide-Angle Imaging Neutral-Atom Spectrometers (TWINS) mission.

Three missions are targeted for launch in FY 2001: MAP in November 2000, CATSAT in July 2001, and GALEX in September 2001. Full-scale spacecraft and instrument development for the SWIFT and FAME missions will continue throughout FY 2001. Mission studies and spacecraft and instrument development for the CHIPS and IMEX missions will continue through FY 2001, in preparation for launches in 3rd and 4th quarter of FY 2002. Development efforts for the TWINS mission will continue throughout FY01; TWIN-A will launch in FY 2003 and TWIN-B will launch in FY 2004. Step-2 selections for SMEX 8 and 9 missions will be made in the 3rd quarter of FY 2001. Announcements of Opportunity for both UNEX and MIDEX missions will be released in FY01.

BASIS OF FY 2001 FUNDING REQUIREMENT

DISCOVERY PROGRAM

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
Stardust *	21,264		
Genesis *	82,894	50,200	7,300
Comet Nucleus Tour *		51,800	45,600
Future Missions	19,742	52,800	135,900
Micromissions			8,000
Total	123,900	154,800	196,800

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The Discovery program provides frequent access to space for small planetary missions that will perform high-quality scientific investigations. The program responds to the need for low-cost planetary missions with short development schedules. Emphasis is placed on increased management of the missions by principal investigators. The Discovery program is intended to accomplish its missions while enhancing the U.S. return on its investment and aiding in the national goal to transfer technology to the private sector. It seeks to contain total mission/life-cycle costs and improve performance by using new technology and by controlling design/development and operations costs.. The program also seeks to enhance public awareness of, and appreciation for, space exploration and to provide educational opportunities.

STRATEGY FOR ACHIEVING GOALS

The strategy for the initial set of Discovery missions was to develop each mission spacecraft within a not-to-exceed target cost of $150 million (FY 1992 constant dollars), and a development schedule to launch of no more than three years from start of development. The Discovery micromissions will complement these missions and be assigned cost and development metrics that are equally as challenging.

The Stardust mission was selected as the fourth Discovery mission in November 1995, with mission management from the Jet Propulsion Laboratory (JPL), and was approved for implementation in October 1996. The mission is designed to gather samples of dust from the comet Wild-2 and return the samples to Earth for detailed analysis. Stardust will also gather and return samples of interstellar dust that the spacecraft encounters during its trip through the Solar System to fly by the comet. Stardust will use a new material called aerogel to capture the dust samples. In addition to the aerogel collectors, Stardust carries three additional scientific instruments. An optical camera will return images of the comet; the Cometary and Interstellar Dust Analyzer (CIDA) was provided by Germany to perform basic compositional analysis of particles encountered in flight; and a dust flux monitor is used to sense particle impacts on the spacecraft. Stardust was launched on a Med-Lite version of the Delta II expendable launch vehicle in February 1999, to rendezvous with the comet in January 2004 and return the samples to Earth in January 2006.

The Genesis mission is designed to collect samples of the charged particles in the solar wind and return them to Earth laboratories for detailed analysis. The mission is led by Dr. Donald Burnett from the California Institute of Technology, Pasadena, CA. JPL will provide the payload and project management, while the spacecraft will be provided by Lockheed Martin Astronautics of Denver, CO. Due for launch in January 2001, Genesis will return the samples of isotopes of oxygen, nitrogen, the noble gases, and other elements to an airborne capture in the Utah desert in August 2003. Such data are crucial for improving theories about the origin of the Sun and the planets, which formed from the same primordial dust cloud.

The goals of the Comet Nucleus Tour (CONTOUR) mission are to dramatically improve our knowledge of key characteristics of comet nuclei and to assess their diversity. The spacecraft will leave Earth orbit, but stay relatively near Earth while intercepting at least three comets. The targets span the range from a very evolved comet (Encke) to a future “new” comet such as Hale-Bopp. CONTOUR builds on the exploratory results from the Halley flybys, and will extend the applicability of data obtained by NASA's Stardust and ESA's Rosetta to broaden our understanding of comets. The Principal Investigator is J. Veverka of Cornell University; the spacecraft and project management are provided by the Johns Hopkins University Applied Physics Laboratory (JHU/APL) of Laurel, MD. Launch is expected in June 2002.

In July 1999, two new Discovery missions were selected for pre-implementation planning, Deep Impact and MESSENGER. In October 1999, the first Discovery Mission of Opportunity, ASPERA-3, was approved for implementation. Deep Impact is designed to fire an 1,100-pound (500 kilogram) copper projectile into the comet P/Tempel 1, excavating a large crater more than 65 feet (20 meters) deep, in order to expose its pristine interior ice and rock. The impactor is separated from the flyby spacecraft 24 hours prior to its impact on the surface of the comet. The impactor has an active guidance system that steers it to impact on the sunlit side of the comet surface. The impactor also relays close-up images of the comet's surface prior to impact back to the flyby spacecraft for downlink to Earth. Optical and infrared instruments on the flyby spacecraft image and spectrally map the impact and resulting crater. The Deep Impact mission is led by Principal Investigator, Dr. Michael A'Hearn from the University of Maryland. The flight hardware and ground systems are developed by Ball Aerospace & Technologies Corp. and JPL. Launch is scheduled for January 2004 in order to impact the comet in July 2005.

The Mercury Surface, Space Environment, Geochemistry and Ranging (MESSENGER) mission will send an orbiter spacecraft carrying seven instruments to globally image and study the closest planet to the Sun. MESSENGER will be implemented by a consortium headed by the Principal Investigator, Dr. Sean Solomon of the Carnegie Institution of Washington. MESSENGER will be designed and built by JHU/APL, in collaboration with industrial partners GenCorp Aerojet (propulsion system) and Composite Optics, Inc. (integrated structure). Instruments and instrument subsystems are being supplied by JHU/APL, NASA/Goddard Space Flight Center, the University of Colorado, and the University of Michigan. The Science Team is comprised of Co-Investigators from various institutions. Launch is expected in 2004.

The Analyzer of Space Plasmas and Energetic Atoms (ASPERA-3) is a Discovery Mission of Opportunity that will provide parts of a scientific instrument to study the interaction between the solar wind and the atmosphere of Mars. It will fly aboard the European Space Agency's Mars Express spacecraft in 2003. The U.S. principal investigator being funded by NASA is Dr. David Winningham of the Southwest Research Institute, San Antonio, TX.

Final selections for the current Discovery AO, released in January, 2000, are expected in 3Q FY 2001. The President's FY 2001 Budget provides additional funding to support a new class of Discovery micromissions that will provide more frequent and varied research opportunities starting with this AO. Discovery micromissions will exploit new mission strategies such as: secondary launch capabilities; flying piggyback on other spacecraft; use of microrover, penetrator, and other micromission capabilities developed for previous NASA missions; or other innovative concepts for very inexpensive solar system science.

SCHEDULE & OUTPUTS

Stardust	
Launch Plan: February 1999 Actual: February 1999	Launched on schedule.
Genesis	
Critical Design Review Plan: May 1999 Actual: July 1999	Confirmation that the mission design is sound. Completed two months late, primarily due to payload design concerns; absorbed out of schedule reserves, with no impact to launch date.
Start Functional Testing Plan: November 1999	Complete Genesis spacecraft assembly and start functional testing. Delayed because of late completion of the Sample Return Capsule and various spacecraft subsystems. Absorbed out of schedule reserves, with no impact to launch date.
Launch Plan: 2^{nd} Qtr., FY 2001	Deliver for launch.
CONTOUR	
Phase B Study Start Plan: October 1998 Actual: April 1999	Start of detailed design studies. Delay did not impact launch schedule.
Preliminary Design Review Plan: 2^{nd} Qtr., FY 2000	Complete a PDR that confirms the design and maintains 15% margins for mass and power.
Complete Imager Breadboard Plan: September 2000	Successfully complete the breadboard of the imager instrument for CONTOUR.
Propulsion System Contract award Plan: FY 2000	Award the contract for the propulsion system following successful PDR.
Critical Design Review Plan: FY 2001	Successful CDR, meeting all program level requirements.

Announcements of Opportunity (AOs)

Step 2 Selection Plan: 3rd Qtr FY 1999 Actual: July 1999	Phase 2 selection leading to Phase B studies.
AO Release Plan: FY 2000	Release an AO for the next Discovery mission.
Mission Selection Plan: FY 2001	New mission selection.

ACCOMPLISHMENTS AND PLANS

Stardust was launched successfully in February 1999, and is operating well.

During FY 1999, Genesis detailed design activities were completed, leading to the Critical Design Review in July 1999. System-level integration and test activities will occur during FY 2000, with delivery to KSC scheduled for early FY 2001 and launch in January 2001.

The CONTOUR mission started preliminary design activities in FY 1999. The Preliminary Design Review and Confirmation Review are scheduled for January 2000. Assuming that the mission is confirmed, development will start in February 2000, leading to a Critical Design Review in early FY 2001.

A Discovery AO was released in March 1998. In November 1998, candidate Discovery missions were selected for further study, including the first Discovery mission of Opportunity, ASPERA-3. In July 1999 NASA selected MESSENGER and Deep Impact for development. ASPERA-3 received approval to proceed into implementation in October 1999. MESSENGER and Deep Impact will continue in the formulation phase through FY 2000, leading to Preliminary Design Reviews in FY 2001, followed by confirmation reviews and (potentially) the start of implementation.

The next Discovery AO was released in January 2000. Final selection(s) are expected in 3Q FY 2001. Starting with this AO, the Discovery program will consider micromissions using such potential new strategies as: secondary launch capabilities; flying piggyback on other spacecraft; use of microrover, penetrator, and other micromission capabilities developed for previous NASA missions; or other innovative concepts for very inexpensive solar system science.

BASIS OF FY 2001 FUNDING REQUIREMENT

MARS SURVEYOR PROGRAM

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
1998 Orbiter and Lander	16,958		
2001 Orbiter and Lander	162,204	117,000	34,200
Mars Telecom Network and Science Micromissions		6,000	35,000
Future Missions	48,538	125,400	257,500
Total	227,700	248,400	326,700

*Total cost information is provided in the Special Issues section

PROGRAM GOALS

The primary objective of the Mars Surveyor Program is to further our understanding of the atmosphere, surface and subsurface composition and structure, biological potential and possible biological history of Mars, and to search for indicators of past and/or present life there. The Mars Surveyor program is a series of small missions designed to resume the detailed exploration of Mars. Missions are planned for launch at every launch opportunity; opportunities occur about every 26 months due to the orbital periods of Earth and Mars. In the near term, missions may either orbit Mars to perform mapping of the planet and its space environment, or actually land on the planet to perform science from the surface. Long-term goals include establishing a sustained presence on Mars and the acquisition and return of carefully selected sample caches. Early missions will facilitate sample returns by identifying those areas of Mars most likely to contain samples of scientific importance, including (potentially) evidence of past biological activity. Missions will also build on one another to support a sustained presence on Mars by emplacing infrastructure at the planet that enhances the science return and overall success of future missions.

STRATEGY FOR ACHIEVING GOALS

This program began in FY 1994 with the development of the Mars Global Surveyor, an orbiter that will obtain much of the data that would have been obtained from the Mars Observer mission. The orbiter carries a science payload, comprised of 6 of 8 spare Mars Observer instruments, aboard a small, industry-developed spacecraft. MGS was launched successfully in November 1996 aboard a Delta II launch vehicle and arrived at Mars in September 1997.

The '98 Mars Orbiter and Lander consisted of the Mars Climate Orbiter (MCO) and the Mars Polar Lander (MPL). The MCO mission was intended to provide information about the cycles of water, carbon dioxide, and dust on Mars. MCO was intended to study the planet's weather for one Martian year, acquiring data to help scientists better understand the Martian climate. The MPL was to focus primarily on Mars' climate and water. The MPL mission would search for near-surface ice and possible surface records of cyclic climate change, and characterize physical processes key to the seasonal cycles of water, carbon dioxide and dust on Mars. MCO launched in December 1998 and MPL launched in January 1999; however, both missions failed upon arrival at Mars.

In light of the failed MCO and MPL, the entire Mars Surveyor Program is undergoing major re-planning activity. Detail on the revised schedules and outputs will be provided once the re-planning is completed.

The Mars '01 mission was to consist of an Orbiter, a Lander and a Rover. The Orbiter would carry three science instruments, the Thermal Emission Imaging System (THEMIS), the Gamma Ray Spectrometer (GRS), and the Mars Radiation Environment Experiment (MARIE). THEMIS would map the mineralogy and morphology of the Martian surface, GRS would globally map the elemental composition of the surface and determine the abundance of hydrogen in the shallow subsurface, and MARIE would characterize aspects of the near-space radiation environment to help gauge the radiation-related risk to human explorers. The Orbiter would also support communication with the '01 Lander. A decision was made in January 2000 to eliminate the Lander and Rover from this launch opportunity. However, as part of the re-planning efforts, some of the '01 Lander flight hardware is being considered for use on future missions. ...

Initiated under the President's Budget request last year, Mars Telecom Network and Science Micromissions will enhance the science return from Mars missions by utilizing micro-spacecraft launched as secondary payloads on commercial French Ariane-V geosynchronous transfer missions and potentially other launch vehicles. Mars Telecom Network is designed to support Mars global reconnaissance, surface exploration, sample return missions, robotic outposts, and eventual human exploration by: 1) Developing a communications capability to provide a substantial increase in data rates and connectivity from Mars to Earth; (2) Developing an in situ navigation capability to enable more precise targeting and location information on approach and at Mars. By developing the capability to provide increased data rates and connectivity, Mars Telecom Network also would enable greater information flow to the public for the purpose of engaging them in the Mars exploration adventure. In essence, Mars Network would be building a publicly accessible, live-video "gateway" to Mars that will enable researchers and the public to explore and experience Mars first-hand. Funding supports one Telecom Network Micromission to Mars in 2003 and at each subsequent 26-month opportunity, as well as a Mars aerostionary telecom orbiter to be launched in 2005 to provide a substantial increase in communications bandwidth and connectivity from Mars to Earth. In addition, funding will provide for Mars science micromissions which will be competitively selected under an open Announcement of Opportunity (AO) process with cost cap.

Funding in Future Missions provides for Mars missions in the 2003 and 2005 launch opportunities, and technologies required for these future Mars missions. The President's FY 2001 Budget provides additional funding in this line to support development and deployment of other potential sustained presence concepts at Mars that could enhance the science return and overall success of future missions.

2001 Mars Surveyor Orbiter and Lander, and beyond missions

Due to the Mars Climate Orbiter and Mars Polar Lander failures, the entire Mars Surveyor Program is currently undergoing major re-planning activity.

Critical Design Review Plan: 2nd Qtr., FY 1999 Actual: April 1999	Confirmation that the design is sufficient to move into full-scale development.
Orbiter & Lander ATLO Start Plan: 1st Qtr., FY 2000 Revised: TBD	Begin Assembly, Test and Launch Operations (ATLO) by integrating major components of the spacecraft into the spacecraft structure.
Orbiter & Lander Science Instruments Plan: 3rd Qtr., FY 2000 Revised: TBD	Deliver Mars 2001 Orbiter and Lander science instruments that meet capability requirements.
Ship Orbiter Plan: 1st Qtr., FY 2001 Revised: TBD	Ship to VAFB launch site.
Ship Lander Plan: 2nd Qtr., FY 2001 Revised: TBD	Ship to KSC launch site.
Orbiter Launch Plan: March FY 2001 Revised: TBD	Launch on schedule.
Lander Launch Plan: April FY 2001 Revised: TBD	Launch on schedule.
Future Mars Surveyor Missions Plan: FY 2000 Revised: TBD	Assuming the Mars Surveyor program architecture is confirmed, meet the milestones for the Mars '03 instrument selection and initiate implementation of the Lander mission. Deliver engineering models of the radio-frequency subsystem and antennae for the radar sounder instrument to ESA (if ESA approves the Mars Express mission), and select the contractors for the major system elements of the Mars Surveyor 05 mission.

ACCOMPLISHMENTS AND PLANS

MGS was launched in November 1996. The spacecraft arrived at its final mapping orbit in January 1999, and started its full mapping operations in March 1999.

The Mars Surveyor 98 mission, an orbiter and a lander, launched in December 1998 and in January 1999, respectively; however, both failed upon arrival at Mars.

The Mars Surveyor '01 spacecraft Critical Design Review took place in April 1999.

Due to the Mars Climate Orbiter and Mars Polar Lander failures, the entire Mars Surveyor Program is currently undergoing major re-planning activity. The detail of the revised schedules and outputs will be provided once the re-planning is completed.

BASIS OF FY 2001 FUNDING REQUIREMENT

MISSION OPERATIONS

	FY 1999	FY 2000	FY 2001
		(Thousands of Dollars)	
HST operations	2,100	2,100	1,500
Other mission operations	115,200	73,300	78,500
Total	117,300	75,400	80,000

PROGRAM GOALS

The goal of the Mission Operations program is to maximize the scientific return from NASA's investment in spacecraft and other data collection sources. The Mission Operations effort is fundamental to achieving the goals of the Office of Space Science program because it funds the operations of the data collecting hardware that produces scientific discoveries. Funding supports satellite operations during the performance of the core missions, plus extended operations of selected spacecraft.

STRATEGY FOR ACHIEVING GOALS AND SCHEDULE & OUTPUTS

The Mission Operations program is working to dramatically reduce costs while preserving, to the greatest extent possible, science output. To do so, it will accept prudent risk, explore new conceptual approaches, streamline management and make other changes to enhance efficiency and effectiveness. The following is a comprehensive list of all Space Science spacecraft that are, or are expected to be, operational at any time between January 2000 and September 2001.

Hubble Space Telescope, HST (launched April 25, 1990; expected operations through ~2010)
HST science operations are carried out through an independent HST Science Institute, which operates under a long-term contract with NASA. Satellite operations, including telemetry, flight operations and initial science data transcription, are performed on-site at Goddard Space Flight Center under separate contract. While NASA retains operational responsibility for the observatory, the Science Institute plans, manages, and schedules the scientific operations.

International Solar-Terrestrial Physics, ISTP: Geotail (launched July 24, 1992; expected operations beyond FY 2001), Wind (launched November 1, 1994; expected operations beyond FY 2001), Polar (launched February 24, 1996; expected operations beyond FY 2001), Solar and Heliospheric Observatory (SOHO) (launched December 2, 1995; expected operations beyond FY 2001)

Wind, Polar, SOHO, and Geotail are the core spacecraft of the ISTP program. Wind measures the energy, mass, and momentum that the solar wind delivers to the Earth's magnetosphere. Wind also carries a gamma ray instrument, the first Russian instrument ever to be flown on a U.S. spacecraft. Polar provides dramatic images of the aurora and complementary measurements to provide a direct measure of the energy and mass deposited from the solar wind into the polar ionosphere and upper atmosphere. SOHO studies the solar interior by measuring the seismic activity on the surface; SOHO also investigates the hot outer atmosphere of the Sun that generates the variable solar wind, as well as UV and X-ray emissions affecting the Earth's upper atmosphere, the geospace environment, and the heliosphere. Geotail is a Japan-U.S. spacecraft that explored the deep geomagnetic tail in its first two years of flight and now is exploring the near-tail region on the night side and the magnetopause on the day side of the Earth.

Compton Gamma Ray Observatory, CGRO (launched April 5, 1991; expected operations until March 2000)
The CGRO's science objectives include studies of very energetic celestial phenomena: solar flares, cosmic gamma-ray bursts, pulsars, nova and supernova explosions, accreting black holes of stellar mass, quasar emissions, and interactions of cosmic rays with the interstellar medium. A gyroscope failed in early December 1999; the observatory is functioning with only two at this time. To help ensure accurate reentry, an initial decision has been made to conduct a controlled de-orbit maneuver in March 2000 while the observatory retains two functioning gyros. However, NASA is conducting studies to determine the feasibility of accurately de-orbiting the satellite with fewer than two gyros to maximize CGRO's research life, and the CGRO de-orbit decision will be re-examined one month prior to the scheduled de-orbit maneuver.

Chandra X-ray Observatory, CXO / Advanced X-ray Astrophysics Facility, AXAF (launched on July 23, 1999; expected operations through ~ FY 2009)
The objectives of Chandra are to: obtain high-resolution x-ray images and spectra in the 0.1-to-10-KeV wavelength range; investigate the existence of stellar black holes; study the contribution of hot gas to the mass of the universe; investigate the existence of dark matter in galaxies; study clusters and superclusters of galaxies; investigate the age and ultimate fate of the universe; study mechanisms by which particles are accelerated to high energies; confirm the validity of basic physical theory in neutron stars; and investigate details of stellar evolution and supernovae.

Relativity Mission, Gravity Probe-B, GP-B (launch scheduled September, 2001; expected operations beyond FY 2001)
The purpose of the Relativity Mission (also known as Gravity Probe-B) is to verify Einstein's theory of general relativity. The theory has only been tested through astronomical observation and Earth-based experiments. The GP-B mission will explore more precisely the predictions of the theory in two areas: (1) a measurement of the "dragging of space" by rotating matter; and (2) a measurement of space-time curvature known as the "geodetic effect".

Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics, TIMED (launch scheduled fall 2000; expected operations beyond FY 2001)
TIMED will explore the Earth's Mesosphere and Lower Thermosphere (60-180 kilometers), the least explored and understood region of our atmosphere.

Galileo (launched October 18, 1989; expected operations through January 2000)
Galileo is executing a series of close flybys of Jupiter and its moons, studying surface properties, gravity fields and magnetic fields, and characterizing the magnetospheric environment of Jupiter and the circulation of its Great Red Spot. In December 1997, the program began the Galileo Europa Mission (GEM), a detailed study of Jupiter's ice-covered moon running through 1999. Galileo will complete its extended-phase "Galileo Europa Mission" (GEM) in January 2000. At the present time NASA is examining science and cost options for a further extension through December 2000; this extension would enable unique science investigations in coordination with a Cassini fly-by of Jupiter, and would generate unique engineering data on the performance of spacecraft in high-radiation-dosage environments.

Cassini (launched October 15, 1997; expected operations through ~ 2008)

Cassini will conduct a detailed exploration of the Saturnian system including: 1) the study of Saturn's atmosphere, rings and magnetosphere; 2) remote and in-situ study of Saturn's largest moon, Titan; 3) the study of Saturn's other icy moons; and 4) a Jupiter fly-by to expand our knowledge of the Jovian System. During the transit from Jupiter to Saturn, Cassini will conduct unique radio-science measurements designed to detect ripples of gravitational field produced by catastrophic events in the galaxy. Cassini will arrive at Saturn in 2004. Proper trajectory is ensured through tracking and targeting maneuvers, and the health of science instruments is maintained by periodic checkouts.

Voyager Interstellar Mission (Voyager 1 launched September 5, 1977; Voyager 2 launched August 20, 1977; expected operations beyond FY 2001)
Voyager 1 and 2 are traveling beyond the planets, continuing to probe the outer heliosphere searching for the boundary between the solar system and the interstellar space.

Ulysses (launched October 6, 1990; expected operations beyond FY 2001)
Ulysses is approaching the south pole of the Sun and will transit the solar poles during 2001 during the peak of the current solar maximum period. The spacecraft is measuring the solar wind properties at high latitudes and is providing a unique 3-dimensional perspective of the heliosphere.

Rossi X-ray Timing Explorer, RXTE (launched December 30, 1995; expected operations beyond FY 2001)
RXTE uses three instruments to conduct timing studies of astronomical X-ray sources.

Advanced Composition Explorer, ACE (launched August 25, 1997; expected operations beyond FY 2001)
ACE is measuring the composition of the particles streaming from the Sun, as well as high-energy galactic cosmic rays.

Far Ultraviolet Spectroscopic Explorer, FUSE (launched June 24, 1999; expected operations beyond FY 2001)
FUSE will measure the amount of cold, warm, and hot plasma in objects ranging from planets to quasars. The objectives for the FUSE mission are to measure the abundance of deuterium produced by the Big Bang, the Milky Way, and distant galaxies; determine the origin and temperature of galactic gaseous clouds and observe interaction between solar wind and planetary atmospheres.

Solar Anomalous and Magnetospheric Particle Explorer, SAMPEX (launched July 3, 1992; expected operations beyond FY 2001)
SAMPEX is measuring the composition of solar energetic particles, anomalous cosmic rays, and galactic cosmic rays.

Fast Auroral Snapshot, FAST (launched August 21, 1996; expected operations beyond FY 2001)
FAST is a low-altitude polar orbit satellite designed to measure the electric fields and rapid particle accelerations that occur along magnetic field lines above auroras. Extremely high data rates (burst modes) are required to detect the presence and characteristics of the fundamental effects taking place.

Submillimeter Wave Astronomy Satellite, SWAS (launched December 5, 1998; expected operations through January 2001)
SWAS studies the chemical composition, energy balance and structure of interstellar clouds and the processes that lead to the formation of stars and planets.

Transition Region and Coronal Explorer, TRACE (launched April 1, 1998; expected operations beyond FY 2001)
TRACE observes, with high resolution, the effects of the emergence of magnetic flux from deep inside the Sun to the outer corona.

Wide Field Infrared Explorer, WIRE (launched March 4, 1999; expected operations as a testbed through FY 2000)
WIRE's primary mission ended when the on-board cryogen was exhausted soon after launch. It is being used as a testbed by other missions to test flight software and other capabilities. In between these engineering tests, some science observations to study astroseismology and the existence of extra-solar planets are performed.

Galaxy Evolution Explorer, GALEX (launch scheduled mid-CY 2001, expected operations beyond FY 2001)
GALEX will use an ultraviolet telescope during its two-year mission to explore the origin and evolution of galaxies and the origins of stars and heavy elements, and to detect millions of galaxies out to a distance of billions of light years. GALEX will also conduct an all-sky ultraviolet survey.

High Energy Solar Spectroscopic Imager, HESSI (launch scheduled July 2000, expected operations beyond FY 2001)
HESSI will observe the Sun to study particle acceleration and energy release in solar flares.

Microwave Anisotropy Probe, MAP (launch scheduled November 2000, expected operations beyond FY 2001)
The MAP Mission will undertake a detailed investigation of the cosmic microwave background to help understand the large-scale structure of the universe, in which galaxies and clusters of galaxies create enormous walls and voids in the cosmos.

Imager for Magnetopause-to-Aurora Global Exploration, IMAGE (launch scheduled February 2000, expected operations beyond FY 2001)
IMAGE will study the global response of the Earth's magnetosphere to the changes in the solar wind.

Student Nitric Oxide Experiment, SNOE (launched February 25, 1998; operations expected through March 2000)
SNOE is a small scientific satellite investigating the effects of energy from the sun and from the magnetosphere on the density of nitric oxide in the Earth's upper atmosphere. SNOE was designed and built, and is being operated, entirely at the University of Colorado at Boulder.

High Energy Transient Explorer 2, HETE-2 (launch scheduled January 2000; operations expected beyond FY 2001)
The primary goal of HETE-2 is to determine the origin and nature of cosmic gamma-ray bursts.

Interplanetary Monitoring Platform-8, IMP-8 (launched October 26, 1973; expected operations beyond FY 2001)
IMP-8 performs near-continuous studies of the solar wind and the interplanetary environment for orbital periods comparable to several rotations of the active solar regions.

Extreme Ultraviolet Explorer, EUVE (launched June 7, 1992; expected operations through end of FY 2000)
EUVE is studying the sky at wavelengths once believed to be completely absorbed by the thin gas between the stars.

Mars Global Surveyor (launched November 7, 1996; expected operations beyond FY 2001)
MGS reached Mars in September 1997 and used aerobraking maneuvers to achieve its desired mapping orbit in March 1999, about one year later than planned due to unanticipated deflections in one of the solar array panels. During aerobreaking, MGS acquired

high-resolution imagery of selected surface features, deleted remnants of a past field, acquired topographic data of both the north and south polar regions as well as selected regions of the northern hemisphere, and acquired surface compositional data of selected areas. In March 1999, MGS began its 2-year prime mapping mission, systematically acquiring data on surface features, atmospheric data, and mapping of magnetic properties. The MGS prime mission will be completed in February 2001.

Mars '01 Orbiter and Lander Operations. Due to the Mars Climate Orbiter and Mars Polar Lander failures, the entire Mars Surveyor Program is currently undergoing major re-planning activity. The detail of the revised schedules and outputs will be provided once the re-planning is completed.

Near Earth Asteroid Rendezvous, NEAR (launched February 17, 1996; expected operations through FY 2001)
NEAR flew by Earth for its final gravity assist in January 1998, and will arrive at its primary target (the asteroid 433 Eros) in February 2000. Originally scheduled for Eros rendezvous in February 1999, the start of prime science operations has been delayed by a premature cut-off during the first orbit insertion engine firing in December 1998.

Stardust (launched February 7, 1999; expected sample return to Earth in 2006)
Stardust will perform activities in support of the five-year cruise to rendezvous with Comet Wild-2.

Genesis (launch scheduled January 2001; expected operations beyond FY 2001)
The Genesis mission will collect samples of the charged particles in the solar wind and return them to Earth laboratories for detailed analysis.

Deep Space 1, DS1 (launched October 24, 1998; expected operations beyond FY 2001)
The New Millennium Program focuses on testing high-risk, advanced technologies in space with low-cost flights. Though testing technologies is the primary goal of the flights, they also allow an opportunity to collect scientifically valuable data. Deep Space 1 has completed 100% of the testing required to validate the technologies, and the mission has been extended, with a new focus on gathering scientific information. Deep Space 1's mission took it by an asteroid on July 28, 1999. When DS1 flew by the asteroid Braille, it was an amazing 26 km away the body. The extended mission will include encounters with two comets.

NASA also participates in the following missions. The foreign partners provide for the operations costs of these missions, with NASA providing science contributions.

- **Astro-E (launch scheduled February 2000; expected operations beyond FY 2001)**
- **Cluster-II (launch scheduled June 2000 and July 2000; expected operations beyond FY 2001).**
- **X-ray Spectroscopy Mission, XMM (launched December 10, 1999; expected operations beyond FY 2001)**
- **Integral (launch scheduled September 2001; expected operations beyond FY 2001).**
- **Nozomi (launched July 3, 1998; expected operations beyond FY 2001)**
- **Advanced Spacecraft for Cosmology Astrophysics, ASCA (launched February 20, 1993; expected operations through FY 2001)**
- **Highly Advanced Laboratory for Communications and Astronomy, HALCA (launched February 12, 1997; expected operations FY 2001)**
- **Yohkoh (launched August 31, 1991; expected operations beyond FY 2001)**
- **Beppo-SAX (launched April 30, 1996; expected operations beyond FY 2001)**

ACCOMPLISHMENTS AND PLANS

Space Science continues to make progress in lowering mission operations costs while preserving the science return from operating missions. The program is utilizing the savings, and seeking additional cost reductions, in order to sustain operations of ongoing missions as long as is merited by the science return. The science community both inside and outside of NASA regularly reviews the mission operations program to ensure that only the missions with the highest science return are funded. In addition, we are launching smaller spacecraft, and engaging in more international collaborations. As a result, NASA expects to be able to support an increasing number of operational spacecraft through FY 2001 despite a smaller MO budget. In total, at the end of FY 2001, we will have approximately 27 operational Space Science spacecraft, in addition to participation in the operations of 12 foreign spacecraft. This compares to 18 at the beginning of FY 1995. As of the end of January 2000, we have 26 operational missions (29 spacecraft), in addition to participation in the operations of 7 foreign spacecraft.

Missions expected to begin operations before the end of FY 2001 include HETE-II (06/00), Astro-E (2/00), IMAGE (02/00), Cluster-II (06/00), HESSI (07/00), GP-B (9/01), TIMED (fall/00), MAP (11/00), Genesis (01/01), 2001 Mars Chemical Mapper (03/01), Catsat (07/01), Integral (09/01), and GALEX (09/01).

BASIS OF FY 2001 FUNDING REQUIREMENT

SUPPORTING RESEARCH AND TECHNOLOGY

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Supporting Research and Technology	916,100	1,179,285	1,302,800
Technology Program	470,200	613,197	740,300
Core Program	211,500	254,496	272,000
Space Science Technology	59,200	92,000	97,100
Cross-Enterprise Technology	152,300	162,496	174,900
Focused Programs	226,600	342,901	424,500
Astronomical Search for Origins	94,700	131,201	133,200
[Construction of Facilities (non-add)]	[2,500]	[2,500]	
Advanced Deep Space Systems	97,100	162,200	181,800
Sun-Earth Connections	20,200	26,600	78,000
Structure & Evolution of the Universe	14,600	22,900	31,500
Flight Validation	32,100	15,800	43,800
Research Program	403,100	529,188	523,600
Research and Analysis	192,200	237,588	211,600
Data Analysis	210,900	291,600	312,000
Suborbital	42,800	36,900	38,900
Balloon Program	13,500	13,300	15,300
Sounding Rockets	29,300	23,600	23,600

PROGRAM GOALS

OVERALL SUPPORTING RESEARCH AND TECHNOLOGY

The Space Science Enterprise's Supporting Research and Technology program is comprised of three major components: the Technology program, the Space Science Research program (consisting of Research and Analysis and Data Analysis) and the Suborbital program. These three elements focus on the activities that occur both before and after space flight mission development and operations. The proper levels of investment in technology, research and suborbital programs are essential to obtaining the high-value scientific results that will enable the Space Science Enterprise to fulfill its mission: to solve the mysteries of the universe including its origins and destiny, explore the solar system, discover planets around other stars, and search for life beyond Earth.

TECHNOLOGY PROGRAM

The goals of the Technology Program are to: (1) lower mission life-cycle costs; (2) develop innovative technologies to enable new kinds of missions; (3) develop and nurture an effective science-technology partnership; (4) stimulate cooperation among industry, academia, and government; and (5) identify and fund the development of important cross-Enterprise technologies.

SPACE SCIENCE RESEARCH PROGRAM

The goals of the Space Science Research and Analysis Program are: (1) to enhance the value of current space missions by carrying out supporting ground-based observations and laboratory experiments; (2) to conduct the basic research necessary to understand observed phenomena, and develop theories to explain observed phenomena and predict new ones; and, (3) to continue the analysis and evaluation of data from laboratories, airborne observatories, balloons, rocket experiments and spacecraft data archives. In addition to supporting basic and experimental astrophysics, space physics, and solar system exploration research for future flight missions, the program also develops and promotes scientific and technological expertise in the U.S. scientific community.

The goal of the Space Science Data Analysis program is to maximize the scientific return from our space missions, within available funding. The Data Analysis program is the source of the enormous scientific return generated from our investments in space hardware. Besides scientific advancements, the Data Analysis program also contributes to public education and understanding through media attention and our own education and outreach activities.

The principal goal of the Suborbital program is to provide frequent, low-cost flight opportunities for space science researchers. The program allows these scientists to fly payloads to conduct research on the Earth's ionosphere and magnetosphere, space plasma physics, astronomy, and high-energy astrophysics. The program also serves as a technology testbed for instruments that may ultimately fly on orbital spacecraft, thus reducing cost and technical risks associated with the development of future space science missions. It is also the primary opportunity for training graduate students and young scientists in hands-on space flight research techniques.

STRATEGY FOR ACHIEVING GOALS

TECHNOLOGY

The Space Science Enterprise’s Technology Program consists of three major elements: core programs, focused programs, and flight validation. These elements are designed to develop technologies from the conceptual stage to the point where they are ready to be incorporated in the full-scale development of science mission spacecraft.

Core Programs are comprised of two major components: Space Science Technology and Cross-Enterprise Technology.

Space Science Technology provides for several activities that cover a broad range of baseline technological capabilities supporting multiple applications. Most of the funding in this area provides for computation and information technologies. One new element of this program is the Intelligent Systems initiative that focuses on exploiting revolutionary advances in information technology to meet the needs of NASA’s missions in the 21st century. Other core capabilities, such as the development of new science instruments, ground system hardware and software for deep space missions, and other elements are also included in this area. The elements of the Space Science Technology Program are described below:

- Explorer Program Technology develops leading-edge technologies to enable partnerships in relatively small technology projects with industry, academia, NASA Field Centers, and other government agencies. These technologies must show application across multiple systems or missions, with an emphasis on meeting Explorer Program technology needs for improved spacecraft and instrument systems, and must also lead to lower mission costs.

- Information Systems provides technology for multidisciplinary science support in the areas of data management and archiving, networking, scientific computing, visualization, and applied information systems research and technology.

- The NASA HPCC Program will accelerate the development, application, and transfer of high-performance computing technologies to meet the science and engineering needs of the U.S. science community and the U.S. aeronautics community. Within this program the Space Science Enterprise funds the Remote Exploration and Experimentation (REE) component, which will develop low-power, fault-tolerant, high-performance, scaleable computing technology for a new generation of microspacecraft.

- Science Instrument Development funds initial technology work on new types of detectors and other scientific instruments. Many of these new instrument concepts are tested and flown aboard sounding rockets or balloons, and may later be adapted for flight aboard future free-flying spacecraft.

- The Planetary Flight Support (PFS) program provides ground system hardware, software, and mission support for all deep space missions. Planetary Flight Support activities are associated with the design and development of multi-mission ground operation systems for deep space and high-Earth-orbiting spacecraft. PFS also supports the development of generic multi-mission ground system upgrades such as the Advanced Multi-Mission Operations System (AMMOS). This new capability is designed to significantly improve our ability to monitor spacecraft systems, resulting in reduced workforce levels and increased operations efficiencies for Cassini and future planetary missions. New missions in the Discovery and Mars Surveyor programs will work closely with the Planetary Flight Support Office to design ground systems developed at minimum cost, in reduced time, with greater capabilities, and able to operate at reduced overall mission operations costs.

- Other Space Science Core Technology provides funding to those technologies that are applicable to multiple science themes within OSS. Technologies eventually move from this category into a focused program (described below) when they have successfully been demonstrated and are ready for infusion into a focused program mission.

- Through the Information Technology Initiative, the President's FY 2001 Budget provides additional funds for the Intelligent Systems Program, which will provide NASA with autonomous and semi-autonomous computational capabilities to enable future missions in deep space, planetary exploration, aerospace applications, and Earth observing systems and data understanding. Self-sustaining networks of robotic explorers in future NASA missions will require intelligent systems technologies far more advanced than current Government or commercial capabilities and are the priority application for the Intelligent Systems Program. Many future missions in all NASA Enterprises will require autonomous robotic systems capable of cooperative behaviors, near-real-time learning, self-healing/self-diagnosis, and on-board decision making. These future NASA-wide mission requirements have led to the identification of four critical areas for Intelligent Systems.

- Automated Reasoning to enable networks of robotic explorers and other NASA missions to build and use systems that reliably make decisions with limited human intervention. The degree of autonomy required is far beyond that achievable today.
- Human-Centered Computing to enable NASA's missions by radically enhancing both individual and team productivity through the inclusion of computer-based agents. As computer-based agents become more capable, and are designed to exercise more autonomy, there is less need to distinguish between computer-based and human agents except with regard to their unique skills.
- Intelligent Data Understanding to enable robots, spacecraft and earth observing satellites to spot interesting trends in raw data and transform raw data into higher-level knowledge. Transforming data into knowledge will enable independent robotic investigation and discovery, and will greatly reduce communications bandwidth requirements.
- Revolutionary Computing to enable advanced spaceborne computing by improving the capabilities of space-ratable processors by two or three orders of magnitude, embracing radically new approaches to computing that are risky but promise substantial payoffs.

The execution strategy of the Intelligent Systems Program emphasizes:

1. Performance by teams of experts from the intramural and extramural communities;
2. Research quality ensured through continuous review by an eminent External Advisory Council of computer scientists;
3. Strategic focus maintained by a Mission Needs Council of senior NASA personnel with mission responsibilities.

The Intelligent Systems Program will allocate approximately 50% of its funds for competition. In order to assure the highest benefit to NASA of extramural participation, however, particular emphasis will be given to research partnerships between NASA and universities/companies that involve some on-site activity at NASA Centers. The goals of the Program are extremely ambitious, and they will be realized only by the highest quality research. To that end, every part of the Program will be reviewed regularly by an eminent board of computer scientists. This External Advisory Council will be constituted of nationally recognized experts in the four focus areas of the program, drawn from key parts of the academic, public and private sectors. The Program will also be regularly reviewed by a Mission Needs Council, made up of senior NASA officials with oversight of relevant mission areas. This group will assure program focus on critical future NASA mission requirements.

The Cross-Enterprise Technology program supports the cross-cutting technology requirements for all NASA Space Enterprises. The technologies are generally multi-mission in nature and this work tends to focus on the earlier stages of the technology life-cycle. The technologies developed under the Cross-Enterprise program form the foundation for most new spacecraft, robotics, and information technologies eventually flown on NASA missions.

A new feature of the Cross-Enterprise Technology program is the use of NASA Research Announcements (NRAs) to broadly announce and compete an increasingly larger portion of the program. This will open up opportunities to a wider community of technology developers and will ensure the excellence of the program through peer-reviewed competition. The implementation of the NRA process in Cross-Enterprise Technology began in FY 1999.

A second change implemented in FY 1999 was the change in Cross-Enterprise Technology program structure. The new program structure is based on integrated, systems-level “thrust areas”, which are more clearly aligned with multi-Enterprise requirements and reflect the way the technology development work is managed. The thrust areas are as follows:

- Advanced Power and On-Board Propulsion: Subsystems and components that handle power generation, energy storage, and in-space propulsion to enable crewed and robotic spacecraft to travel faster and deeper into space, with longer mission duration.

- Sensors and Instrument Components: Breakthrough technologies for a wide range of remote sensing and observational capabilities for use in Space Science and Earth Science applications.

- Distributed Spacecraft: Precision-formation-flying technologies, spacecraft constellations, and fleet control technologies.

- High Rate Data Delivery: Technologies to more efficiently collect, transmit, receive, store and access data from operational missions.

- Micro/Nano Spacecraft: Technologies to enable smaller, lower mass spacecraft with greater functionality. This area will also develop technologies to integrate developments from other thrust areas, such as miniature power, propulsion, instruments, and other components, into functioning miniature spacecraft.

- Surface Systems: Technologies for spacecraft to operate and explore on the surface, below the surface, or in the atmospheres of planetary and other celestial bodies.

- Thinking Space Systems: Development of thinking, inquisitive, self-commanding systems that can recognize objects or phenomena of scientific interest and then conduct observations accordingly.

- Ultralight Structures and Space Observatories: Technologies enabling the deployment of large, lightweight space structures. These include precision deployment capabilities, membrane and inflatable structures, and high performance materials.

- Next Generation Infrastructure: Development of technologies to vastly improve the ability to conceive, design, test, and operate future space systems.

Beginning in FY 2000, additional funding for the Cross-Enterprise Technology program budget was provided to support two new initiatives: Gossamer Spacecraft and Next Decade Planning.

The Gossamer Spacecraft initiative supports the ultralight structures and space observatories thrust area to develop and demonstrate the deployment, control, and utility of thin-film deployable structures. Technologies developed in this area could support several future applications: solar sail propulsion, large aperture astronomical observatories, large aperture remote sensing, large-scale power collection and transmission in space, and interstellar precursor missions.

Next Decade Planning is supporting improved cross-agency planning with the objective of improving technology selection through the ongoing development and refinement of a robust set of potential civil space programs that could be undertaken in the next decade.

The President's FY 2001 Budget includes an augmentation to the Space Science budget for Nanotechnology ($5 million). NASA will participate in the National Nanotechnology Initiative by pursuing fundamental investigations in quantum effects, atom imaging and manipulation, nanotube research, and other related areas. These investigations are expected to lead to applications such as: lighter, smaller, and more capable spacecraft; biomedical sensors and medical devices; powerful, small, low-power computers; radiation-hard electronics; thin-film materials.

In addition, the Cross-Enterprise Technology program includes the Space Solar Power project, which is developing goals and objectives, detailed roadmaps, and technology investment priorities through ongoing system studies and initial technology activities.

Focused Programs are dedicated to high-priority technologies needed for specific science missions. An aggressive technology development approach is used that allows all major technological hurdles to be cleared prior to a science mission's development phase. Technology activities can encompass developments from basic research all the way to infusion into science missions. Focused Programs also includes mission studies -- the first phase of the flight program development process. Scientists work collaboratively with technologists and mission designers to develop the most effective alignment of technology development programs with future missions. This collaboration enables intelligent technology investment decisions through detailed analysis of the trade-offs between design considerations and cost. In order to ensure that the decisions resulting from mission studies are realistic and can be implemented, the studies will employ new techniques for integrated design and rapid prototyping.

The FY 2001 budget estimate includes four categories of activities under focused programs. These categories correspond to the four scientific themes of the Space Science Enterprise: Astronomical Search for Origins, Advanced Deep Space Systems Development (Solar System Exploration), Sun-Earth Connections, and Structure and Evolution of the Universe. These elements are described below:

- Astronomical Search for Origins Technology develops critical technologies for studies of the early universe and of extra-solar planetary systems. Included are large lightweight deployable structures, precision metrology, vibration isolation and structural quieting systems, optical delay lines and large lightweight optics. Missions supported in this area include the Space Interferometry Mission (SIM), Next Generation Space Telescope (NGST), the Space Technology 3 mission and Terrestrial Planet Finder (TPF), as well as the provision of interferometry capability to the ground-based Keck telescopes. This line also funds construction of the Optical Interferometry Development Laboratory at the Jet Propulsion Laboratory in FY 1999 and FY 2000.

- Advanced Deep Space Systems Technology provides for the development, integration, and testing of revolutionary technologies for solar system exploration. Emphasis is on micro-avionics, autonomy, computing technologies, and advanced power systems. Funding is included in this line for the Center for Integrated Space Microsystems (CISM) and the Advanced Power System project. Funding in this area supports a Europa orbiter and a Pluto/Kuiper Express mission. Technology developed in this area also supports Solar Probe (a Sun-Earth Connections mission), which shares a significant amount of common technology with Europa Orbiter and Pluto/Kuiper Express. The President's FY 2001 Budget provides additional funding in the outyears in Advanced Deep Space Systems to support a sustained presence at potential high priority research targets in the solar system.

- Sun-Earth Connections (SEC) Technology develops the technologies necessary for missions focused on observing the Sun and the effects of solar phenomena on the space environment and on the Earth. Technology funded in this area supports missions now under study such as STEREO, Solar-B, and Solar Probe, as well as future SEC missions.

  The President's FY 2001 Budget includes an augmentation for the Living With a Star Initiative ($20 million in FY 2001). Living With a Star is a set of missions and enhancements to current programs designed to study solar variability and its effects on humanity. This initiative will fundamentally change the emphasis of the Sun-Earth Connections theme by having dual objectives, one studying solar-terrestrial physics to understand basic natural processes (current program) and the other stressing investigations into how solar variability affects humans and technology. Understanding the Sun is of supreme importance because we have increased dependence on space-based systems and soon will have a permanent presence of humans in Earth orbit. Solar variability can affect: civilian and military space systems; national defense; human space flight; electric power grids; GPS signals; high-frequency radio communications; long-range radar; microelectronics and humans in high-altitude aircraft; and terrestrial climate. Prudence demands that we fully understand the solar effects on these systems. In addition, given the massive economic impact of even small changes in climate, we should fully understand both natural and anthropogenic causes of global climate change. The Living With a Star Initiative capitalizes and expands upon investments being made in the Solar Terrestrial Probes program in missions such as TIMED, STEREO, and Solar-B, as well as the ST-5 microsat technology demonstration mission in the Flight Validation Program. LWS will also pursue partnerships with other federal agencies.

- Structure and Evolution of the Universe Technology provides for the development of technologies to study the large-scale structure of the universe, including the Milky Way and objects of extreme physical conditions. SEU missions are aimed at explaining the cycles of matter and energy in the evolving universe, examining the ultimate limits of gravity and energy in the universe and forecasting our cosmic destiny. Technology funded in this area supports missions now under study, such as FIRST and GLAST, as well as future SEU missions, particularly Constellation-X.

The table below shows the currently planned missions for each of the focused programs, and indicates the planned start of implementation and the funding (in thousands of dollars) for each mission.

Focused Program Missions	Implementation Start	FY 1999	FY 2000	FY 2001
Origins				
SIM	FY 2002	34,165	40,450	48,000
NGST	FY 2004	32,190	46,560	61,540
TPF	FY 2008	1,600	4,000	10,000
ST3	FY 2002	9,200	8,000	17,000
Keck Interferometer	FY 1998	16,400	13,700	6,400
Deep Space Systems				
Europa Orbiter	FY 2000	15,400	57,300	93,000
Pluto/Kuiper Express	FY 2000	700	7,000	19,600
Structure & Evolution of the Universe				
FIRST	FY 2001	6,635	16,110	20,800
GLAST	FY 2002	4,850	4,850	8,730
Sun-Earth Connections				
Solar-B	FY 2000	5,000	9,600	19,500

STEREO	FY 2001	7,000	8,300	23,600
Solar Probe	FY 2003	400	3,200	7,400

The **Flight Validation Program** (previously referred to as the New Millennium Program) provides a path to flight-validate key emerging technologies to enable exciting science missions. Through the Flight Validation program, high-value technologies are made available for use in the Space Science program without imposing undue cost and risk on individual science missions. This program has been restored in this budget, but has also been restructured to increase its levels of openness and competitiveness, to reduce the size and cost of the missions, and to ensure focus on technology demonstration, versus science data gathering. The program will include validation of both complete systems and subsystems. At planned funding levels through 2005, it is anticipated that two small ($40-50 million each) and one medium ($100-150 million) system validations will be enabled every four years, along with two-to-three subsystem validations per year, including carrier and secondary launch. Partnerships with industry, universities, and other government agencies will continue to be pursued, where feasible, to maximize both the return on investment in technology development and rapid infusion.

RESEARCH

The Space Science Research and Analysis Program carries out its goals and objectives by providing grants to universities and nonprofit and industrial research institutions, as well as by funding scientists at NASA Field Centers and other government agencies. Approximately 1,500 grants are awarded each year after a rigorous peer review process; only about one out of four proposals is accepted for funding, making this research program among the most competitive in government. This scientific research is the foundation of the Space Science Enterprise. Key research activities include the analysis and interpretation of results from current and past missions; synthesis of these analyses with related airborne, suborbital, and ground-based observations; and the development of theory, which yields the scientific questions to motivate subsequent missions. The publication and dissemination of the results of new missions to scientists and the world is another key element of the Research and Analysis Program strategy, since it both inspires and enables cutting-edge research into the fundamental questions that form the core of the mission of the Space Science Enterprise. With the exception of a proprietary period of up to one year for some missions, 100% percent of the data from current and past Space Science missions is openly available to the public via the internet. (These proprietary periods are being phased out.)

The OSS NRA for Research Opportunities in Space Science (ROSS) solicits proposals for basic investigations to seek to understand natural space phenomena across the full range of space science programs relevant to the four OSS science themes. Participation in this program is open to all categories of U.S. and non-U.S. organizations including educational institutions, industry, nonprofit institutions, NASA Centers, and other Government agencies. Minority and disadvantaged institutions are particularly encouraged to apply. Recommendations for funding are based on the independent evaluation of each proposal's science and technical merits, and its relevance to the OSS objectives as described in the NRA.

The Space Science Data Analysis program supports scientific teams using data from our spacecraft. Depending on the mission, scientists supported may include Principal Investigators who have built scientific instruments and are guaranteed the data from those instruments, Guest Observers who have successfully competed for observing time, and researchers using archived data from current or past missions. Data Analysis funding also supports a number of critical "Science Center" functions that are necessary to the operation of the spacecraft but do not involve the actual commanding of the spacecraft. For instance, the planning and scheduling of spacecraft observations, the distribution of data to investigators, and data archiving services are all supported under Data Analysis.

SUBORBITAL

The Suborbital program provides the science community with a variety of options for the acquisition of in-situ or remote sensing data. Aircraft, balloons and sounding rockets provide access to the upper limits of the Earth's atmosphere. Activities are conducted on both a national and international cooperative basis.

Balloons provide a cost-effective way to test flight instrumentation in the space radiation environment and to make observations at altitudes above most of the water vapor in the atmosphere. In many instances, it is necessary to fly primary scientific experiments on balloons, due to size, weight, cost considerations or lack of other opportunities. Balloon experiments are particularly useful for infrared, gamma-ray, and cosmic-ray astronomy. In addition to the level-of-effort science observations, the program has successfully developed balloons capable of lifting payloads greater than 5000 pounds. Balloons are now also capable of conducting a limited number of missions lasting 9 to 24 days, and successful long-duration flights are being conducted in or near both polar regions. The Balloon contract is managed by the GSFC Wallops Flight Facility (WFF). Flight operations are conducted by the National Scientific Balloon Facility (NSBF), a government-owned, contractor-operated facility in Palestine, Texas.

Analytical tools have been developed to predict balloon performance and flight conditions. These tools are being employed to analyze new balloon materials in order to develop an ultra-long-duration balloon (ULDB) flight capability (approximately 100 days), based on super-pressure balloons. An integrated management team has been established to develop and test the balloon vehicle and balloon-craft support system.

Sounding rockets are uniquely suited to perform low-altitude measurements (between balloon and spacecraft altitude) and to measure vertical variations of many atmospheric parameters. Sounding rockets are used to support special areas of study, such as: the nature, characteristics and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including aurora production and energy coupling into the atmosphere; and the nature, characteristics and spectra of radiation of the Sun, stars and other celestial objects. In addition, sounding rockets allow several science disciplines to flight test instruments and experiments being developed for future space missions. The program also provides a means for calibrating flight instruments and obtaining vertical atmospheric profiles to complement data obtained from orbiting spacecraft. Launch operations are conducted from facilities at WFF, Virginia; White Sands, New Mexico; and Poker Flat, Alaska, as well as occasional foreign locations. A performance-based contract was awarded February 1999 to allow the government to transition away from operational control. The contract is managed by the GSFC/WFF.

In an effort to broaden the education opportunities using experiments built by students and flown on sounding rockets and stratospheric balloons, a Student Launch Program has been established for U.S. institutions of higher learning. This provides students, for the bachelor's through master's degrees, an opportunity to work on a reasonably complex project from its inception to its end, in a timeframe tenable within their academic careers. NASA expects to continue its competitive selection of this program with release of a new research announcement in FY 2000.

SCHEDULE & OUTPUTS

Technology Program

Space Science Core Technology

First-Generation computing testbed Plan: 2nd Qtr FY 1999 Revised: 3rd Qtr FY 2000	For HPCC Remote Exploration and Experimentation (REE) program, install first-generation scaleable embedded computing testbed operating at 30-200 MOPS/watt. Difficulties with the hardware design have delayed delivery.
Demonstrate scaleable computer for spaceborne applications Plan: 3rd Qtr. FY 1999 Revised: 4th Qtr. FY 2000	For HPCC Remote Exploration and Experimentation (REE) program, demonstrate scaleable spaceborne applications on first-generation embedded computing testbed. All of the applications have been delivered and demonstrated on a commercial parallel computer and are awaiting delivery of the testbed.

HPCC Plan: FY 2001	Demonstrate a real time capability with software implemented fault tolerance for embedded scalable computers. Real time performance latencies of less than 20 milliseconds are to be sustained at fault rates characteristic of deep space and low Earth orbit (LEO).
Information Systems Plan: FY 2000	Information Systems R&T will demonstrate the search, discovery, and fusion of multiple data products at a major science meeting.
Information Systems Plan: FY 2000	Information Systems R&T will accomplish and document the infusion of five information systems R&T efforts into flight projects for the broad research community.
Information Systems Plan: FY 2001	Information Systems R&T will demonstrate Virtual Observatory capability from investigator workstation for multi-wavelength discovery, analysis, and visualization across collective set of space and ground astronomical surveys; demonstrate a Virtual Mars capability simulating rovers navigating Mars terrain, for planning and design of Mars '03 and '05 missions.
Information Systems Plan: FY 2001	Information Systems R&T will demonstrate a Virtual Mars capability simulating rovers navigating Mars terrain, for planning and design of Mars '03 and '05 missions.
Explorer Program Technology Plan: FY 2001	Complete 45 Explorers Technology Investigations selected in FY99.
Explorer Program Technology Plan: FY 2001	Implement awards for additional investigations planned for selection in FY00.
Intelligent Systems Program Management Plan: FY 2000	The Program will establish the program investment portfolio and organiz the Program office and management structure.
Intelligent Systems Initial Procurement Plan: FY 2000	Initial IS research procurement targeted toward attracting academic and industry collaborators with NASA.
Intelligent Systems NAR Plan: FY 2000	A Non-Advocate Review will be held.
Intelligent Systems Plan: 1st Qtr FY 2001	Develop an initial set of organization-wide knowledge management strategies based on Operations Center-identified priorities and opportunities.
Intelligent Systems External Assessment Plan: 4th Qtr FY 2001	Program Assessment reviewed by External Advisory Council & Mission Needs Council.

Intelligent Systems Awards Plan: FY 2001	Awards will be concomitant with the beginning of the 2001 program year. A second research opportunity cycle will begin in late 2001, targeted toward a second set of awards in mid-2002.
Intelligent Systems Architectures Plan: 3rd Qtr FY 2001	Develop an initial set of promising revolutionary computing architectures for relevant space applications.
Intelligent Systems Data Understanding Methodologies Plan: 4th Qtr FY 2001	Structure Earth Science and Vehicle maintenance data sets for use by the developers of advanced Data Understanding methodologies, and perform initial tests of such methodologies.
Intelligent Systems Automated Reasoning Plan: 4th qtr FY 2001	Integrate automated reasoning and other software components with the objective of designing and specifying a modular autonomy architecture for robotic networks.

Cross-Enterprise Technology

Conduct on-orbit Ranger telerobotic flight experiment Plan: 4th Qtr. FY 99 Revised: Under review	This experiment will demonstrate multiple on-orbit robotic servicing capabilities relevant to science payload servicing and Space Station assembly and maintenance. The original target launch date of FY 2000 has been postponed due to STS manifesting considerations. A FY 2001 launch opportunity is currently being pursued.
Develop Wide-Band Low-Power Electronically-Tuned Local Oscillator Sources up to 1.3 THz Plan: 3rd Qtr., FY 1998 Revised: 3rd Qtr., FY 2000	A wide-band local oscillator (with 15% bandwidth) has been demonstrated operating at frequencies up to 0.5 THz. Construction of components operating at higher frequencies is underway. Lab demonstration of local oscillators operating at frequencies up to 1.9THz is planned for 3Q00. Technology approach and development schedule changed to reflect new advances in amplifier technology.
NRA Release Plan: 2nd Qtr., FY 1999 Actual: 1st Qtr., FY 1999	Release NASA Research Announcement (NRA) for Cross-Enterprise technology development. NRA was combined with the Explorer Technology NRA.
Task Selections Plan: 4th Qtr., FY 1999 Actual: 3rd Qtr., FY 1999	Select tasks from NASA Research Announcement (NRA) for Cross-Enterprise technology development following competitive review. NRA was combined with the Explorer Technology NRA, and awards were made 3rd Qtr., FY 1999.
Task Selections Plan: 4th Qtr., FY 2000	Select first set of tasks from NASA Research Announcement (NRA) for Cross-Enterprise technology development (released November 1999) following competitive review.

Task Selections Plan: FY 2001	Select second set of tasks from NASA Research Announcement (NRA) for Cross-Enterprise technology development (released November 1999) following competitive review.
Full and Open Competition Plan: End of FY 2000	One hundred percent of tasks subjected to full and open competition and/or external non-advocate review by end of FY 2000.
Gossamer Spacecraft NRA Release Plan: 2nd Qtr., FY 2000	Release first annual Gossamer Spacecraft NRA seeking proposals for technical concepts and predevelopment activities.
Gossamer Spacecraft NRA Selections Plan: 4th Qtr., FY 2000	Make initial awards in response to proposals for Gossamer Spacecraft technical concepts and predevelopment activities.

Focused Programs

Origins

ST-3 System Arch. Review Plan: August 1999 Revised: October 2000	System Architecture & Requirements Review. Delay due to significant program rephasing and replanning to bring ST-3 and TPF schedules into alignment, resulting in extended Phase B for ST-3.
ST-3 Technology Development Plan: FY 2001	Successfully complete PDR as well as project and spacecraft CDR.
Space Interferometry Mission (SIM) Non-Advocate Review Plan: 2nd-4th Qtr. FY 1999 Revised: 1st Qtr., FY 2002	Conduct the preliminary non-advocate review of the high precision astrometry and synthetic aperture imaging technologies for space-based interferometers. Key features include optical collectors on a 10-meter baseline and 10-milli-arcsecond synthesized imaging. Due to additional technology development needed to retire risk before entering Phase C/D, SIM launch date has been delayed to FY 2006. As a result, the NAR is now scheduled for the 1st quarter of FY 2002.
SIM Testbed Demonstration Plan: May 2000	Demonstrate, in May 2000, that an rms optical path difference can be controlled at 1.5 nanometers, operating in an emulated on-orbit mode.
SIM SRR Plan: FY 2001	Complete System Requirements Review (SRR) and initiate Phase B.
SIM Nulling Demonstration Plan: FY 2001	Demonstrate stabilization for nulling to one nanometer. Nulling is required to remove starlight that would wash out SIM's view of planets in other solar systems.
Keck Fringe Detection	Development of the interferometer program for connecting the twin Keck 10-meter telescopes

Plan: FY 2000	with an array of four two-meter class outrigger telescopes will be tested by detecting and tracking fringes with two test siderostats at two- and ten-micron wavelengths.
Keck Technology Development Plan: FY 2001	Combine 2 Keck telescopes; install first outrigger telescope.
NGST Technology Testbed Development Plan: FY 2000	Complete the NGST Developmental Cryogenic Active Telescope Testbed (DCATT) phase 1, measure ambient operation with off-the-shelf components, and make final preparations for phase 2, the measurement of cold telescope operation with selected "flight-like" component upgrades.
NGST Inflatable Sun Shield Development Plan: FY 2001	Inflatable Shield in Space (ISIS) ready to fly on Shuttle; release AO for Science Instrument; down-select to a single phase 2 prime contractor.
NGST Science Instrument AO Plan: FY 2001	Release AO for NGST Science Instruments.
NGST Phase 2 Down-Select Plan: FY 2001	Down-select to a single phase 2 prime contractor.
TPF Technology Development Plan: FY 2000	Complete and deliver a technology development plan for the Terrestrial Planet Finder (TPF) mission. This infrared interferometer requires the definition of technologies that will not be developed or demonstrated by precursor missions.
TPF Architectural Definition Plan: FY 2001	Award architectural definition contracts.
TPF Phase 2 Industrial Contracts Plan: FY 2001	Develop RFP for second phase of industrial contracts.
TPF Starlight Nulling Plan: FY 2001	Test starlight nulling breadboard.

Deep Space System (DSS) -

CISM Curriculum Plan: 4th Qtr. FY 1998	Develop university curriculum for two CISM technology thrust efforts: Systems on a Chip, and Revolutionary Computing Technologies. Curriculum for Systems on a Chip completed in July

Actual: 4th Qtr. FY 1999	1998, and implemented at the University of Illinois-Chicago. Curriculum for Revolutionary Computing Technologies completed in FY 1999, and has been implemented at Notre Dame University.
CISM Technology Development Plan: 3rd Qtr FY 2000 Actual: FY 1999	The 1st generation system on a chip prototype was fabricated earlier this year at MIT Lincoln Labs and has been delivered to JPL ahead of schedule. It will begin performance testing during FY 2000.
CISM Technology Development Plan: 3rd Qtr., FY 2000	Deliver first engineering model of an integrated avionics system.
CISM Technology Development Plan: FY 2001	Demonstrate and deliver prototype advanced power transistor [0.35 micron SOI (Silicon On Insulator) CMOS (Complementary Metallic Oxide Semiconductor)].
CISM Active Pixel Sensor Plan: FY 2001	Demonstrate Active Pixel Sensor with advanced processing capabilities on a single chip.
X-2000 Testbed design Plan: 4th Qtr FY 1999 Actual: 4th Qtr FY 1999	First delivery of an integrated and tested spacecraft avionics testbed design. The X2000 testbed design has been completed and is being prepared for operational use.
X-2000 Technology Development Plan: FY 2000	The first engineering model (EM-1) of the X2000 First Delivery will be delivered. Successful development includes the integration of all EM-1 hardware, the functional verification of delivered hardware and software, and the ability to support ongoing testing, hardware integration, and software verification for delivered software.
X-2000 Technology Development Plan: FY 2001	Deliver engineering model and flight set of avionics.
Solar System Exploration (non-Mars) First Mission C/D Start Plan: FY 2000 Revised: 1st Qtr., FY 2001	Successfully complete a preliminary design for either the Europa Orbiter or Pluto-Kuiper Express mission (whichever is planned for earlier launch) that is shown to be capable of achieving the Category 1A science objectives with adequate cost, mass, power, and other engineering margins. Preliminary Design Reviews (PDRs) delayed due to problems experienced with Advanced RTG, a major technology feeder.
Europa Orbiter Avionics Engineering Model I&T Plan: July 2000	Begin integration and test of the Avionics Engineering Model.
Future Deep Space Systems Planning Plan: FY 2001	Deliver X-2003 Level 1-3 Requirements Documents, define subsystem, complete definition of system architecture.

Future Deep Space Multi-Functional Structures Plan: FY 2001	Demonstrate intermediate-level multi-functional structures (MFS).
ARPS Plan: FY 2000 Actual: N/A	Fabricate and test 15 prototype AMTEC cells and complete the final design of Alkali Metal Thermo-Electric Converter (AMTEC) cells (3/00). Complete the final design for a 75-watt ARPS (4/00). Begin the prototype AMTEC 4-cell lifetime test and begin qualification unit fabrication (9/00). Project terminated during FY 1999 due to insufficient technical progress. Alternative advanced power program being formulated.
DS-4 Critical Design Review Plan: September 2000 Actual: N/A	Complete the system CDR for the New Millennium Deep Space-4 (Champollion) project before the end of FY00, including successful completion of the avionics subsystem CDR and the mechanical subsystem CDR. The ST-4/Champollion project was cancelled on July 1, 1999 to address other Space Science high-priority requirements.

SEC

Complete Phase A and Transition to Detailed Design for Solar-B Instruments Plan: 4th Qtr. FY 1999 Actual: October 1999	Complete concept development for focal plane instrumentation for the optical telescope and X-ray telescope. Phase B effort started November 1999.
Deliver Solar-B Electrical Engineering Models Plan: September 2000	Complete and deliver for testing Solar-B's four Electrical Engineering Models.
Deliver Solar-B Telescope Engineering Model Plan: FY 2001	Deliver engineering model of the optical telescope and x-ray telescope.
STEREO Technology Development Plan: FY 2000	Complete STEREO Phase A studies by June 2000, including the release of an AO for investigations with specific instruments and selection of the formulation phase payload.
STEREO Technology Development Plan: FY 2001	Successfully complete Phase B effort, including Confirmation Review.

Solar Probe Technology Development Plan: FY 2001	Begin Solar Probe prototype thermal shield fabrication.
Complete Living With a Star Strategic Plan Plan: March FY 2001	Complete Living With a Star Project Strategic Plan for the OSS Strategic Plan.
Future ST Probes Technology Development Plan: FY 2001	Complete preliminary concept definitions for spacecraft systems and instruments for Magnetospheric Multiscale.

SEU

FIRST Technology Development Plan: 4th Qtr. FY 1999 Actual: 4th Qtr FY 1999	Develop Key Technologies in the area of cryo-coolers, mixers, bolometer arrays, and light-weight 3.5-meter telescope to prepare for C/D start in FY 2000 and launch in FY 2006.
FIRST Instrument Performance Plan: FY 2000	Demonstrate performance of the Superconductor-Insulator-Superconductor (SIS) mixer to at least 8hv/k at 1,120 GHz and 10hv/k at 1,200 GHz. The U.S. contribution to the ESA FIRST is the heterodyne instrument, which contains the SIS receiver.
FIRST Technology Development Plan: FY 2001	Complete the qualification mirror (QM) fabrication.
GLAST Prototype Instrument Performance Plan: FY 2000	The prototype primary instrument for GLAST will demonstrate achievement of the established instrument performance level of angular resolution of 3.5 degrees across the entire 20-MeV (million electron volts) to 100-GeV (giga-electron volts) energy range.
GLAST Technology Development Plan: FY 2001	Conduct successful NAR for instrument development, project definition, and interface development.

Flight Validation Program

ST-5 Critical Design Review Plan: FY 2001	Complete ST-5 Critical Design Review.
ST-6, ST-7, and ST-8 Project Selections Plan: FY 2001	Competitively select two to three subsystem technology demonstrations.
ST-6 and ST-7 Project Approval Plan: FY 2001	Complete ST-6 and ST-7 project approval.
ST-6 Critical Design Review Plan: FY 2001	Complete ST-6 Critical Design Review (CDR).

<u>Research Program</u>

<u>Space Science Research and Analysis</u>

Issue FY 2000 NASA Research Announcement (NRA) Plan: February 2000	Issue FY 2000 NRA for Research Opportunities in Space Science (ROSS).
Issue FY 2001 NASA Research Announcement (NRA) Plan: 2nd Qtr., FY 2001	Issue FY 2001 NRA for Research Opportunities in Space Science (ROSS).
Astrobiology Institute Operations Plan: FY 1999 Actual: FY 1999	Initiate the Astrobiology Institute's operations by linking up to eight institutions and engaging approximately 50 investigators to promote publication of interdisciplinary research and foster effective public education and outreach on research on life in the universe. Eleven member institutions have established video and whiteboard conferencing capabilities, and over 70 investigators are engaged in research.
Astrobiology Research Plan: FY 2001	High-priority studies identified in the Astrobiology Roadmap will be carried out, the National Astrobiology Institute will conduct institute-wide functions using internet/video conferencing capabilities (ie. Executive council meetings, science seminars, group collaborations, education/outreach), and Institute research publications will reflect its interdisciplinary nature.

Suborbital Program

Balloon Program

Balloon Flights Actual: FY 1999	16 flights were flown with 94% balloon and mission success.
Balloon Flights Plan: FY 2000	Plans call for 26 worldwide balloon missions.
Balloon Flights Plan: FY 2001	Plans call for 26 worldwide balloon missions.

Sounding Rockets

Sounding Rocket Flights Actual: FY 1999	23 missions were launched with 100% success and 96% mission success.
Sounding Rocket Flights Plan: FY 2000	Plans call for 25 worldwide sounding rocket missions.
Sounding Rocket Flights Plan: FY 2001	Plans call for 25 worldwide sounding rocket missions.

ACCOMPLISHMENTS AND PLANS

Core Technology Program

Space Science Core

The Explorer Technology initiative will identify, develop, infuse and transfer technologies that enable and enhance opportunities for frequent scientific investigations at the highest science value per unit cost through Category III AO awards for technology development, NRAs, and partnering opportunities. MIDEX Category III awards, new partnering arrangements and Explorer Technology NASA Research Announcement (NRA) awards for technology development in instrument components, optical systems for instruments, data systems hardware and software, and guidance navigation and control were made in FY 1999. SMEX Category III awards, and more new partnering agreements are planned for FY 2000, as well as the issuance of a new NRA, with awards planned for FY 2001.

The Information Systems program will continue to provide reliable access for research communities and the public to obtain science data through the Planetary Data System, National Space Science Data Center, Space Telescope Science Institute, and High Energy Astrophysics Science Archive Research Center. Continuing advances in development and infusion of evolving information technology will increase the level of interoperability to support interdisciplinary research.

The Intelligent Systems program will complete a Non-Advocate Review (NAR) in FY2000. The program will begin development of intelligent agents (e.g. robotic teaming, vehicle health monitoring, etc.) and intelligent data mining tools during FY 2001. Work will also be initiated in such high payoff areas as: information displays and visualization tools for distributed collaboration; verification and validation algorithms for distributed computing architectures; automated reasoning and data interpretation methodologies for an advanced vehicle health monitoring system; advanced data mining and data fusion tools for distributed, massive data sets; methods and tools to emulate human cognitive skills for scientific discovery and mission operations; plus adaptive, learning-based control methods for enhanced aircraft safety. These activities will continue through the life of the program and will result in deliveries of fundamentally new capabilities throughout the FY 2001-2005 time period.

In High Performance Computing and Communication, the Remote Exploration and Experimentation project will continue to support the development of a first-generation testbed for scaleable spaceborne applications as well as embedded scaleable high-performance computers.

Science instrument development will continue to develop initial technologies for new sensors, detectors, and other instruments in support of specific space science research objectives. In many cases these technologies will be flown and validated as part of the suborbital program, either on balloons or rockets.

Planetary flight support will continue to develop the Advanced Multi-Mission Operations System ground system upgrade, which will enable greater efficiency in the monitoring of spacecraft systems allowing us continued operation at a reduced level of overall mission operations costs.

Cross-Enterprise Technology

Activities within the Cross-Enterprise Technology program continue to focus on reducing spacecraft size, weight, and operating costs. The following are among many accomplishments for FY 1999:

- In Advanced Power and On-Board Propulsion, supported flight validation (>3,500 hours) of the 2.6-Kilowatt Ion Propulsion Engine on DS-1 by accumulating more than 7,400 hours of successful life–cycle testing on the ground. This is the first use in space flight of a technology that has been in various stages of development for over 30 years. The technology will be used to reduce greatly the flight time and the cost of planetary missions and Discovery Program missions.

- In Thinking Space Systems funded ground-based activities in support of Flight validation of software for autonomous control of spacecraft. Known as Remote Agent, the software operated NASA's Deep Space-1 spacecraft and its futuristic ion engine during two experiments that started on May 17, 1999. For two days the Remote Agent ran on the on-board computer of Deep Space-1, more than 60,000,000 miles (96,500,000 kilometers) from Earth. The tests were a step toward robotic explorers of the 21st century that are less costly, more capable and more independent from ground control. Remote Agent is Co-Winner of NASA's 1999 Software of the Year Award.

- In Surface Systems, demonstrated that an innovative concept, the Subsurface Explorer, can, in a laboratory testbed, penetrate to a depth of at least 8 meters using only 100 Watts. This development of a small (20 kg), self-contained robotic device capable of penetrating significant distances underground, will enable exploration and sample return from the Nucleus of a Comet and from soil layers below the Mars permafrost.

- The Micro/Nano Spacecraft Thrust Program demonstrated in ground tests a prototype micro-star tracker — of low mass (< 1 kg) and low cost ($25K) — for attitude control of micro-spacecraft. It is aimed at replacing the state-of-the-art tracker weighing about 5kg and costing $400K.

- The Surface System Program field-tested a rover with inflatable wheels and inflatable solar arrays (8 kg, 40 Watts). The projected range of the rover is 10 km. This design permits climbing over obstacles as high as about 0.5 m with mass savings of well over an order of magnitude compared to a rigid design.

- The Ultralightweight Structures and Space Observatories Program developed a 1/2-scale model of the inflatable NGST sunshield to cool the telescope to cryogenic temperature passively. The inflatable structure enables a ten-fold reduction in launch volume and two-fold reduction in sunshield weight.

- In the Next Generation Infrastructure thrust, the Smart Assembly Modeler (SAM) is now in beta testing. SAM assembles flight engineering models from independently created – as well as platform independent -- part or component flight engineering models, allowing component design engineers to predict and assess how these independent subsystems will perform when integrated into a real system.

- Space Solar Power issued a NASA Research Announcement, made peer-reviewed awards in selected areas and initiated coordinated efforts at several NASA centers.

In FY 2000 work has commenced on two new items in the Cross-Enterprise Technology program: Gossamer Spacecraft, and Next Decade Planning. Gossamer Spacecraft has begun developing ultralight structures and other technologies required to demonstrate the deployment, control, and utility of thin-film deployable structures. Next Decade Planning is supporting the development and refinement of concepts and technologies that are critical to developing a robust set of civil space initiatives during the FY 2001 to FY 2010 timeframe. Examples of concepts that will be addressed by this initiative include: direct imaging of extrasolar planets, establishment of permanent robotic outposts on other worlds, human space flight in support of science goals at potential research site beyond low-Earth orbit, leveraging potential future commercial space infrastructure for research and exploration, and enabling the direct involvement of the public in space exploration.

The most recent Cross Enterprise Technology Development Program (CETDP) NASA Research Announcement (NRA) was released during the first quarter of FY 2000. The plan for the CETDP is to release one three-year NRA per year. It is anticipated that funding will be approximately $20M per year for each NRA. The total NRA funding will reach half of the CETDP funding level in FY 2002. This first NRA release represents a combination of the first (FY1999) and second (FY2000) NRAs. Current plans call for a single review of all proposals, followed by two sets of selections, one in the last quarter of FY 2000 and one in the first quarter of FY 2001. Over 2100 Notices of Intent have been received and the number is increasing daily. Indications are that the number of actual proposals could easily exceed 3000, which will be a record for the Office of Space Science. Proposals are due by Feb. 15, 2000.

Focused Programs

The Astronomical Search for Origins focused program continued technology development and mission design activities in FY 1999. Among the accomplishments were:

- SIM concept design down-select was made in October 1999. The decision is to go with the Classic Design. It should be noted that both the Classic and Alternative designs evolved and improved significantly as a result of the design competition.

- Selections and awards were made for Phase I of the NGST Advanced Mirror Technology concept studies in FY 1999. These studies will proceed into Phase II in FY 2000. In addition, NGST entered Phase A in early FY99, and will stay in Phase A throughout FY00.

- Construction continued on the KECK Outrigger domes and telescopes throughout FY 1999.

- Realignment of the ST-3 schedule to match TPF schedule requirements was completed in FY 1999. ST-3 entered Phase B in early FY 2000, and will enter into implementation in FY 2002.

The Origins focused program will fund mission design and technology development for six elements in FY 2000 and 2001:

- An interferometry technology validation flight (New Millennium Space Technology-3; formerly included in the flight validation program) to demonstrate the concept of separated spacecraft interferometry. This 6-month flight demonstration, scheduled for launch in 2005, will utilize two spacecraft to validate precision formation flying and space interferometry, technologies that are required for the Terrestrial Planet Finder (TPF) mission (see below).

- The Space Interferometry Mission (SIM) will be the world's first long-baseline operational optical space interferometer. It is scheduled for launch in FY 2006, assuming successful technology development. This mission has dual objectives: science and technology. The science objectives include: astrometric detection of planets around other stars in our galaxy (mostly those of Uranus' mass but also some as small as several Earth masses); and precision location of very dim stars to an unprecedented accuracy (SIM will be a factor of 250 better in accuracy on stars 1000-times fainter than the best catalog currently available). The technology objective is to serve as the precursor to the future interferometry-based TPF mission. Specific technologies to be developed include precision laser metrology, controlled optics, optical delay lines, vibration isolation and structural quieting systems, and deployable structures. An Announcement of Opportunity (AO) for SIM science instruments will be released in February 2000.

- The Next Generation Space Telescope (NGST) will combine large aperture and low temperature in an ideal infrared observing environment. NGST will allow astronomers to study the first protogalaxies, the first star clusters as they make their first generation of stars, and the first supernovae as they release heavy chemical elements into the interstellar gas. New technologies include precision-deployable structures, very large, low-area-density cold mirrors and active optics, and low-noise, large format infrared detectors. The target launch date is FY 2007, also assuming successful technology development.

- Keck Interferometer Phase 1 enables NASA to capitalize on its significant previous investment in the Keck Observatory in Hawaii by connecting Keck's twin 10-meter telescopes into an 85-meter-baseline interferometer. Installation of the Beam-Combining hardware on Mauna Kea was initiated in FY 2000. The first test fringes from the combined telescopes are planned by the end of FY 2000. When Phase 1 is completed in the fall of 2000, the Keck interferometer will become the world's most powerful ground-based optical instrument. Keck will be able to directly detect hot planets with Jupiter-size masses and will also be able to characterize clouds of dust and gases permeating other planetary systems. Phase 2 will add four 1.8-meter outrigger telescopes to the interferometer complement which will allow astrometric detection of Uranus-sized planets and will provide the capability to image protoplanetary discs. Phase 2 is planned for completion in FY 2002.

- Terrestrial Planet Finder (TPF) is aimed at the ultimate goal of the NASA's Origins program: to find Earth-like planets. Each of the precursor Origins activities, including the Space Infrared Telescope Facility (SIRTF), provides knowledge and technology needed for the design of the TPF. As currently envisioned, TPF will either be a large single-spacecraft interferometer or a group of several spacecraft (possibly copies of NGST) flown in precise formation. Thus, the experience and understanding gained in each step of the Origins program will be needed to make TPF successful. A request for proposals was released for TPF architecture studies in January 2000. Award is planned for three 18-month studies in April 2000.

- The Optical Interferometry Laboratory at the Jet Propulsion Lab will enable the development and verification of interferometry systems operating at the extremely high levels of precision required to meet the objectives of the Origins program. The new facility will include a high bay, a low bay, a ground support equipment room and three development laboratories.

The Advanced Deep Space Systems focused program will continue to provide for the development, integration, and testing of revolutionary technologies for solar system and planetary exploration. Technologies developed in this area will also support a Solar Probe mission, which utilizes many of the same systems and technologies as the Europa Orbiter and Pluto/Kuiper projects. The primary focus of the Deep Space Technology Program is to reduce the mass and volume of planetary spacecraft, toward the goal of a "spacecraft on a chip."

In FY 1999, CISM completed fabricating the 1st generation system on a chip prototype at MIT Lincoln Labs and delivered it to JPL for performance testing. Also during FY 1999, NASA completed development of university curricula for two CISM technology thrust efforts: Curriculum for Systems on a Chip, and Curriculum for Revolutionary Computing Technologies. X2000 delivered an integrated and tested spacecraft avionics testbed design during FY 1999. This testbed is now being prepared for operational use. Europa/Pluto initiated Phase A mission design studies and technology development in FY 1998 and continued the studies and technology activities throughout FY 1999. These missions entered phase B in early FY 2000 and will complete formulation phase by the end of FY 2000.

The ST-4/Champollion project was cancelled on July 1, 1999. NASA took this action to ensure that the Space Science program has sufficient financial resources to manage its remaining programs and projects within its projected budget availability. This mission was a relatively low priority in the Space Science program for three reasons. First, it was not required to achieve the objectives in the Space Science Strategic Plan. Second, some of the most important science that would have been done on ST-4 will be accomplished by the European Rosetta mission. Finally, the ST-4 mission had gradually moved away from the original intention of the Flight Validation Program, which is to validate emerging technologies to enable science missions. By terminating the current ST-4 mission, we will achieve a net savings of greater than $200 million in the FY 1999 – FY 2004 timeframe. We have preserved the technology validation objectives of ST-4 that are required for the Mars Surveyor Program and the Europa Orbiter by applying a portion of the savings from ST-4 to those programs.

Key technology partnerships will be maintained with national laboratories and research agencies such as:
• Air Force Research Labs to develop radiation-hard microelectronics technology
• Sandia National Laboratory to support MEMS technology
• Department of Energy to support Stirling thermal-to-electric conversion technology
• MIT Lincoln Labs to continue advanced semiconductor technology
• DARPA to continue ultra-scale computing and quantum computing technology

Emphasis will be on micro-avionics, autonomy, computing technologies and advanced power systems. The development of AMTEC thermal-to-electric conversion technologies in the Advanced Radioisotope Power System (ARPS) project was terminated during FY 1999 due to a lack of sufficient technical progress. The Advanced Power Systems project is being refocused in FY 2000 to pursue alternate technologies, such as Stirling conversion systems. The focus of this activity is to develop a robust, high-efficiency, low-mass, low–cost, 100-watt-class electrical power source for deep space missions, along with supporting technologies for radioisotope power sources in the milliwatt and 10-watt classes for future projects. Performed in partnership with the Department of Energy (DoE), this activity will increase the efficiency of thermal-to-electric converters, reduce the cost and time to fabricate, test and deliver flight power systems, and provide breakthrough technology and/or multifunctional radioisotope power sources for future microspacecraft.

Since FY 1998, the Center for Integrated Space Microsystems (CISM) has been developing the advanced computing and avionics technologies that will enable miniaturized autonomous robotic spacecraft for deep-space exploration. These technologies will comprise the core of the advanced spacecraft development. A world-class facility for microelectronics system design, advanced simulation, rapid prototyping, and integration and test was started at JPL in FY 1999, and is being completed in FY 2000. This facility will be electronically linked to industrial partners and collaborating universities as part of the distributed Collaborative Engineering Workbench technology.

Mission planning will support design and definition of the Europa Orbiter mission and the Pluto/Kuiper Express mission. The formulation efforts for both these projects will be completed during FY 2000. Due to changes in the power systems design and increases in the launch vehicle costs, the launch schedule for these missions is being re-evaluated.

The focus for Sun-Earth Connections mission planning and technology activities will be directed toward the following future missions:

- Living With a Star is a set of missions and enhancements to current programs designed to study solar variability and its effects on humanity. This project will establish a Solar Dynamics Observatory, Solar Sentinals, Geospace Dynamics Network and initiate data analysis and modeling targets for space weather objectives. LWS will include partnerships with other federal agencies, including the National Science Foundation, United States Air Force, and National Oceanic and Atmospheric Administration.

- Solar-B, a joint mission with the Japanese (ISAS spacecraft and launch), consists of a coordinated set of optical, EUV, and X-ray instruments that will apply a systems approach to the interaction between the Sun's magnetic field and its high-temperature, ionized atmosphere. Technologies required by this mission include lightweight, stable optics and high-accuracy polarimetry for high-resolution (~0.1 arc sec) measurements of solar magnetic fields. Solar-B's expected launch date is FY 2004.

- STEREO is conceived as two spacecraft in solar orbit. These spacecraft are to provide stereo imaging of solar corona, track solar mass ejections from the Sun to Earth using radio and optical instruments, and measure in-situ the solar wind and energetic particles (solar mass ejections appear to be a primary source of intense solar energetic particles events). STEREO's anticipated launch date is FY 2004.

- Solar Probe, the first close fly-by of a star (within 4 solar radii), requires a thermal shield to protect the payload from the Sun without releasing material that would contaminate the in-situ measurements. Because of its deep space flight trajectory, Solar Probe also requires many of the technologies being developed within the Advanced Deep Space Systems focused program, such as radiation hardening for the Jupiter swing-by and solar fly-by. The target launch date is FY 2007.

- Magnetospheric Multiscale is to be comprised of five spacecraft flying in formation, to study simultaneously the global behavior of the magnetosphere and the magnetospheric processes at the small scales where many of the basic interactions occur.

- Global Electrodynamics is a mission made up of four spacecraft, which will have an "atmospheric dipping" capability for investigating the electromagnetic coupling between the solar wind and upper atmosphere.

- Magnetospheric Constellation will support a fleet of 10-100 nanosats using radio tomography and in-situ instrumentation to provide instantaneous global maps of plasma and field structures in the magnetosphere.

Structure and Evolution of the Universe mission planning and technology activities focus on development and demonstration of technologies necessary to implement the space missions outlined in the recent SEU Science and Technology Roadmaps. The priority missions include:

- Gamma Ray Large Area Space Telescope (GLAST). GLAST will study cosmic sources of high-energy particles and radiation (up to 300 GeV) with a large area, wide field-of-view, imaging telescope, using solid-state particle tracking technology. This technology is being developed in cooperation with DOE.

- ESA's Far Infrared and Submillimeter Space Telescope (FIRST). The U.S. participation on the FIRST mission substantially enhances the science goals with four key technologies: lightweight telescopes, cryocoolers, bolometer arrays, and heterodyne receivers.

- Constellation X-ray Mission. Constellation-X will use multiple satellites to enable a very large collecting area. Each spacecraft will be equipped with a high-throughput telescope for the low-energy band up to 10 keV, and three grazing-incidence telescopes for the high-energy band.

Flight Validation

The DS-1 spacecraft successfully flew by asteroid Braille in July, successfully completed its primary mission of testing twelve advanced technologies in late September 1999 and is now on an extended mission. The mission has exceeded almost all of its technology validation requirements by conducting more extensive tests than had been planned,. As one dramatic example, the spacecraft's experimental xenon ion engine, which was required to thrust for a minimum of 200 hours, has been operated for nearly 1,800 hours.

The two DS-2 miniature probes carrying ten experimental technologies were to have impacted Martian soil on December 3, 1999 but each probe failed to respond to communication efforts by NASA engineers. Review boards have been set up to study the cause of the apparent loss and explore ways to prevent a recurrence.

The Flight Validation program has been refocused to maintain its emphasis on technology validation, risk mitigation, and rapid infusion of technology into science missions through a competitive process. Additional funding has also been provided in FY 2001-2005. Three very small satellites called the Nanosat Constellation Trailblazer mission were selected in August 1999 as the NMP Space Technology-5 (ST-5) demonstrator. Each Trailblazer spacecraft will be an octagon 16 inches across and 8 inches high, and each will have booms and antennas that will extend after launch. Results from the Trailblazer mission will be used to design future missions using constellations of lightweight (about 44 pounds), highly miniaturized autonomous spacecraft. With the funding added to the program, it is anticipated that 2-3 subsystem technology demonstrations will be competitively selected in FY 2001 and each year thereafter, and that two small system demonstrators and one medium-sized demonstrator will be competitively selected and developed in the 2001-2005 period.

Research

Research and Analysis

The Space Science R&A program continued to produce exciting scientific results in 1999. Many of the recent discoveries of planets around other stars were supported by NASA's Space Science R&A program. Particularly exciting was the announcement of the first known multi-planet system around a sun-like star. In addition, evidence was presented for a planet in orbit around a pair of stars. By the end of 1999, the number of known planets around other stars reached nearly 30. While the potential detection of Earth-like planets remains in the future, per our plans for the Origins program, these findings increase the likelihood that such planets may be common in the universe, and are already leading to advances in theoretical models of planetary system formation.

Research continues on the Martian meteorite ALH84001 with most findings pointing to a non-life origin of many of the features. However, there are still several lines of mineralogical evidence that may point to life processes (e.g., origins of some of the iron oxides). The team that presented the evidence in 1996 for past Mars life in ALH84001 announced in 1999 that they had found similar features in two other Martian meteorites. In other meteorite news, scientists announced the discovery of liquid water in two different meteorites, probably a remnant of the solar system's fiery beginning and a possible clue to how the sun and planets formed. A rock-hunting robot was dispatched to Antarctica in December, in an attempt to turn up the first meteorites discovered by a machine rather than a human. This capability would enhance the future collection of meteorites in Antarctica, and could have future implications for autonomous robots on other solar system bodies.

The Near-Earth Object (NEO) Program Office at JPL continues to focus on the goal of locating at least 90 percent of the estimated 2,000 asteroids and comets that approach the Earth and are larger than about 2/3-mile (about 1 kilometer) in diameter, by the end of the next decade. These are objects that are difficult to detect because of their relatively small size, but are large enough to cause global effects if one hit the Earth. Detection, tracking, and characterization of such objects are all critical. The Near-Earth Asteroid Tracking (NEAT) project has been enhanced by the addition of high-tech, computerized electronic upgrades to an existing telescope with a much greater field of view than the one previously used by NEAT. The fastest rotating asteroid ever found, spinning on its axis every 11 minutes, was announced by an international team of astronomers. Finally, scientists using radar data created the best image ever of a near-Earth object.

In recognition of the interrelationship between the origin and evolution of life and the origin and evolution of planets, a new program within the framework of Astrobiology was initiated in 1997. A multi-disciplinary Astrobiology Institute was established with members from 11 geographically distributed research institutions, linked through advanced telecommunications. Examples of research accomplishments for the past year include a genetic study demonstrating that the ancestors of major groups of animal species may have begun populating Earth 1.2 billion years ago, more than 600 million years earlier than indicated by their fossil remains. It was demonstrated that methanogenic bacteria could grow in conditions simulating the subsurface of Mars if even a small amount of water is available. And a microbial world was discovered hidden deep beneath the frozen Antarctic ice; this could help us learn more about how life can survive under extreme conditions on other planets or moons.

NASA is considering construction of a unique national lab at Ames Research Center, built by an industry consortium. This facility would complement the Astrobiology Institute, and would be dedicated to simulating and analyzing the chemical and biological characteristics of detectable, habitable worlds. The facility would be open to the community through competitive, peer-reviewed selection.

Data Analysis

NASA's Space Science spacecraft continue to generate a stream of scientific discoveries. Many of these findings are of broad interest to the general public, as demonstrated by widespread media coverage. Recent highlights include results from Hubble Space Telescope, Mars Global Surveyor, Cassini, Compton Gamma-Ray Observatory (CGRO), Galileo, Transition Region and Coronal Explorer (TRACE), Advanced Composition Explorer (ACE), Solar and Heliospheric Observatory (SOHO), Wind, Polar, the Solar Anomalous and Magnetospheric Participle Explorer (SAMPEX), and the Lunar Prospector. However, many other Space Science spacecraft have been "in the news" and extremely scientifically productive as well. NASA is also finding ways to partner with the education community in order to strengthen science, technology, and mathematics education. Listed below are the top science stories of the past year from NASA Space Science missions.

- EXPANDING UNIVERSE. In addition to the thousands of breathtaking images that the Hubble Space Telescope (HST) continued to deliver, one result was a long-awaited, scientific coup: Hubble scientists calculated a more accurate value for how fast the universe is expanding after eight years of painstaking measurement. The rate of expansion, called the Hubble Constant, is essential to determining the age and size of the universe. Measuring the Hubble Constant was one of the three major goals for the telescope when it was launched in 1990.

- LATEST FROM MARS. Mars Global Surveyor Provided the First Global 3-D Map of Mars. An impact basin deep enough to swallow Mount Everest and surprising slopes in Valles Marineris highlight a global map of Mars that will influence scientific understanding of the red planet for years. Generated by the Mars Orbiter Laser Altimeter (MOLA), the high-resolution map represents 27 million measurements gathered in 1998 and 1999.

- JOURNEY TO SATURN. The Cassini spacecraft, currently on a journey to Saturn, completed a highly accurate swing-by of Earth in August. This was necessary to give Cassini a boost in speed, sending it toward a rendezvous with Saturn and its moon Titan in 2004. Cassini's next encounter will be with Jupiter in December 2000 as the giant planet provides the last gravitational assist to the spacecraft on its journey to Saturn.

- IMAGES OF AN EXPLODING UNIVERSE. Astronomers racing the clock managed to take the first-ever optical images of one of the most powerful explosions in the Universe -- a gamma ray burst -- just as it was occurring on January 23, 1999 Such bursts occur with no warning and typically last for just seconds. The science team was alerted to the new gamma ray burst by the Compton Gamma Ray Observatory (CGRO) and, within 22 seconds, was able to capture an image of the burst at optical wavelengths. Discoveries like this are essential to unlocking the secrets of our universe.

- CRAB NEBULA. In July, the Space Shuttle Columbia successfully carried to orbit the Chandra X-Ray Observatory (CXO), the third of NASA's "Great Observatories," joining the Hubble Space Telescope and the Compton Gamma Ray Observatory. The results to date from Chandra have been dramatic. After barely two months in space, CXO took a stunning image of the Crab Nebula, the most intensively studied object beyond our Solar System, and revealed something never seen before: a brilliant ring around the nebula's heart. Its performance and images continue to delight astronomers.

- OUR STAR, THE SUN. A new feature near the surface of the Sun, termed "solar moss" because its weird, sponge-like appearance resembles the plant, has been discovered by the Transition Region and Coronal Explorer (TRACE) spacecraft. Solar Moss is a thin region in the solar atmosphere where the temperature soars from ten thousand to millions of degrees. This discovery offers a new way to study the mass and energy flows in this region. It also helps us understand how the large magnetic loops in the Sun's outer atmosphere, the corona, form out of the highly intermittent magnetic fields on the Sun's surface. Studying the solar moss may ultimately shed light on the long-standing problem of how the corona is heated to million-degree temperatures.

- IMAGES OF IO FIERY LAVA. Galileo is getting close-in looks at Io, Jupiter's closest satellite. During a recent close flyby of Io, the spacecraft observed a fiery lava fountain shooting more than a mile above the moon's surface. The images show a curtain of lava erupting within a giant volcanic crater.

- SOLAR WIND AND THE AURORAL DISPLAY AT THE NORTH POLE. From May 10-12, 1999, the solar wind that blows constantly from the Sun virtually disappeared in the most drastic and longest-lasting decrease ever observed. Dropping to a fraction of its normal density and to half its normal speed, the solar wind died down enough to allow physicists to observe particles flowing directly from the Sun's corona to Earth. This severe change in the solar wind also drastically changed the shape of Earth's magnetic field and produced a rare auroral display at the North Pole. The following missions provided the data on this unusual event: ACE, SOHO, Wind, Polar, Geotail, IMP-8, SAMPEX, and Lunar Prospector.

Suborbital Program

In FY 1999, 16 balloons were flown for the core program, of which 15 were successful flights. The unsuccessful flight was reflown successfully within 10 days. Capping years of technology development, the long duration ballooning (LDB) capability has been repeatedly demonstrated and is now fully operational. Work is underway to demonstrate an ultra-long duration capability in 2001.

Collaboration work with JPL is focusing on ULDB technologies that could be useful for planetary exploration programs such as Mars or Venus. The first demonstration of a 60,000 m^3 (ULDB) super-pressure balloon was launched in October 1999.

The sounding rocket program achieved 100% flight and 96% science success in FY 1999. Additionally, an active campaign in Norway occurred during this period. Work on the sounding rocket operations procurement resulted in announcement of an award in December 1998. The transition to this new approach toward managing the program was successfully demonstrated in FY 1999.

BASIS OF FY 2001 FUNDING REQUIREMENT

SPACE SCIENCE INVESTMENTS

	FY 1999	FY 2000	FY 2001
	(Thousands of Dollars)		
Enterprise Contribution to Academic Programs..................	[10,200]	[10,200]	13,200
Education Program			1,500
Minority University Research and Education Program.......	[10,200]	[10,200]	11,700
Total	[10,200]	[10,200]	13,200

In carrying out its Education Program, NASA is particularly cognizant of the powerful attraction the Space Science mission holds for students and educators. The unique character of Space Science exploration, scientific, and technical activities has the ability to captivate the imagination and excitement of students, teachers, and faculty, and channel this into an investment which support NASA's Education Program.

In fulfilling its role to support excellence in education as set forth in the NASA Strategic Plan, the NASA Education Program brings students and educators into its missions and its research as participants and partners. NASA provides the opportunity for educators and students to experience first hand involvement with Space Science Enterprise scientists and engineers, facilities, and research and development activities. Examples of such opportunities include the Learning Technologies Program, a new Undergraduate Internship Program, and the Graduate Student Researchers Program. The participants benefit from the opportunity to become involved in research and development endeavors, gain an understanding of the breadth of Space Science activities, and return to the classroom with enhanced knowledge and skills to share with the entire education community. Detail as to how this funding is utilized is located under the NASA Education portion of the budget.

The Space Science Strategic Enterprise investments in higher education institutions include Federally mandated outreach to the Nation's Historically Black Colleges and Universities (HBCUs) and Other Minority Universities (OMUs), including Hispanic-Serving Institution and Tribal Colleges and Universities. This outreach is achieved through a comprehensive and complementary array of strategies developed in collaboration with the Office of Equal Opportunity Programs. These strategies are designed to create a broad-based, competitive aerospace research capability within Minority Institutions (MI's). This capability fosters new aerospace science and technology concepts by integrating Space Science Enterprise-related cutting-edge science and technology concepts, practices, and teaching strategies into MI's academic, scientific and technology infrastructure. As result, increasing the production of more competitive trained U.S. students, underrepresented in NASA-related fields who, because of their research training and exposure to cutting-edge technologies, are better prepared to enter graduate programs or the workplace. Other initiatives are focused on enhancing diversity in the Space Science Strategic Enterprise's programs and activities. This includes exposing faculty and students from HBCUs and OMUs, and students from under-served schools, with significant enrollments of minority students, to the Enterprise's research efforts and outcomes, educational programs, and activities. To support the accomplishment of the Enterprise's mission, these programs are implemented through NASA Centers and JPL. The Centers and JPL support the MUREP through use of their unique facilities, program management and grant administration, and commitment of their personnel to provide technical assistance and assist in other facets of program implementation. Extensive detail as to how this funding is utilized is located under the MUREP portion of the budget.